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[FOURTH SERIES.]

Art. XIV.—*On the Ratio of Radium to Uranium in some Minerals;* by Bertram B. Boltwood.

The experiments which will be described in this paper were undertaken with the object of determining the relative proportions of radium and uranium present in certain mineral substances.*

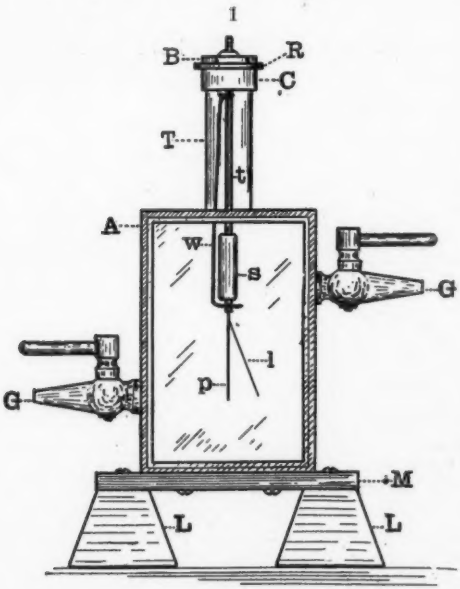
The method which has been used for the quantitative estimation of the radium depends upon the electrical measurement of the radium emanation which is given off when a known quantity of the mineral is dissolved or decomposed by suitable chemical reagents and this solution is allowed to stand for several days in direct communication with a closed glass vessel. Another plan which has also been tried is to decompose the mineral completely in an open vessel and to heat the solution to boiling in order to expel all of the accumulated emanation. The solution was then sealed up in a closed glass vessel and the emanation allowed to accumulate for a given period, at the end of which it was removed and measured†.

The testing of the emanation was carried out in an air-tight electroscope (fig. 1) similar in principle and design to that described by C. T. R. Wilson. It consisted of a rectangular brass case *A*, 15^{cm} high, 10^{cm} wide and 4·5^{cm} deep. The

*A preliminary notice in which some of the results were given has already appeared in the Engineering and Mining Journal, lxxvii, p. 756, and in the London Nature, lxx, p. 80.

†In a paper by Strutt (Proc. Royal Soc., lxxiii) some measurements of the amounts of radium emanation given off by certain minerals on heating are described. Some experiments which I have made show that samarskite, on heating to low redness, gives off only 10 per cent, and on heating to bright redness only 20 per cent, of the emanation set free when this mineral is completely decomposed with hot sulphuric acid.

walls of this case were 6mm in thickness and were grooved on the edge to a depth and width of 3mm. Two plates of plate-glass 3mm thick fitted closely into the grooves of the case and the joint was made air-tight by the use of hot sealing-wax. The glass plates formed the front and back of the electroscope case. The case was provided with two brass stopcocks, *G*, and carried on the top a glass tube *T*, 2·5cm in diameter and 7·5cm in length. The gold-leaf, *l*, was attached to the brass plate *p*, which was 5cm long and 1cm wide, and was soldered to a brass



rod 1·5cm long and 3mm in diameter. The rod *s* of cast sulphur, 4cm long and 1cm in diameter, served as an insulating support for the gold-leaf and was attached at the top to a brass rod 12cm in length and 3mm in diameter. The brass rods were connected firmly to the sulphur support by warming the rods to above the melting point of sulphur and pushing them a short distance into the ends of the sulphur rod. Fitted to the top of the tube *T* was a brass ring, *C*, into which screwed the cap *B*, also of brass. Through the latter passed a short glass tube 1cm in diameter and contracted somewhat at the top. This glass tube was filled with melted sulphur, which was then allowed to solidify. The end of the rod *t* was then warmed and pushed through the sulphur plug until it extended about 5mm beyond

it, and the joint was made still tighter by the application of a small quantity of melted sealing-wax. Suspended by a small hook near the top of the rod t was a soft iron wire w, which extended to below the sulphur rod and terminated in a loop which surrounded the rod supporting the plate p. When hanging in its normal position this wire did not touch the lower rod, but on bringing a small magnet near the tube T the wire was deflected and established a metallic circuit between the upper rod and the gold leaf. The plate p and the metal portions of its supports were heavily gold-plated to prevent tarnishing. All of the joints and crevices were filled with sealing wax except that between B and C, which was closed air-tight by a rubber washer, R, between them. By unscrewing the cap B the gold-leaf and its supports could be removed from the case.

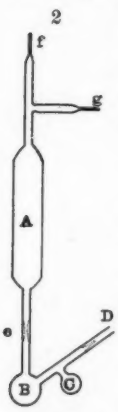
The electroscope was attached by screws to an iron plate, M, which in turn was fastened to two lead ingots, L, L, weighing about seven pounds each. The whole apparatus was therefore very steady and connections could be made at the cocks without fear of altering the adjustment.

For charging the gold-leaf a large stick of sealing-wax was used. This was rubbed lightly on the clothing and approached to the top of the rod t, the wire w being brought at the same time into contact with the plate p by means of a small magnet. On rubbing the rod gently with the sealing-wax a sufficient charge was imparted to the gold leaf to produce the desired deflection. After removing the sealing-wax stick and the magnet, the top of the rod and cap were touched with the finger. This method of charging worked very well during the dry weather of winter and early spring but became troublesome when the air of the laboratory grew moister, and has therefore been superseded by the use of a battery of small storage cells giving a potential of from 300 to 400 volts.

The fall of the gold-leaf due to leak of the electric charge was observed by means of a microscope mounted on a separate support in front of the electroscope. This microscope consisted of a Bausch and Lomb combination of a 2-inch eye-piece and a 1½-inch objective mounted in an ordinary draw-tube. The diameter of the field was about 4^{mm} and the eye-piece contained a glass scale divided into nine divisions, which were further subdivided into tenths; each tenth of a division therefore corresponded to about $0{\cdot}044^{mm}$.

The radium emanation given off by a known weight of mineral substance was collected in the apparatus shown in fig. 2. This was made entirely of glass and consisted of an elongated bulb, A, connected by a tube with the smaller bulb B, which in turn was connected with the still smaller bulb C. A weighed

quantity of the very finely powdered mineral was introduced from a long, thin weighing-tube into the bulb B, and, except where the reagent afterwards employed was concentrated sulphuric acid, enough water to cover the mineral was then introduced into B from a small pipette. C was then filled with the acid used to decompose or dissolve the mineral and, the capillary tubes at f and g having been already closed, the tube CD was drawn out into a short capillary and sealed off in the flame of a blast-lamp. At the moment of sealing off, a slight negative pressure was created in the interior of the apparatus by drawing out a small portion of the air through a rubber tube attached at D.



The apparatus was tipped until the acid in C ran over into B, and B was then warmed gently until the mineral contained in it had been entirely decomposed. The apparatus was then allowed to stand undisturbed for several days to come into equilibrium and the tube connecting A and B was then drawn out into a short capillary and sealed off at e. The bulb A, separated in this manner from the rest of the apparatus, was then allowed to stand for about two hours in order that any rapidly decaying emanation (thorium or actinium) might be entirely removed. The air and radium emanation contained in A were then transferred to the electroscope in the following manner: The capillary tube at e was first notched with a file and then broken off under the surface of a strong sodium hydroxide solution. Because of the diminished pressure in A, several cubic centimeters of the sodium hydroxide solution would be drawn into the bulb. A short rubber tube filled with water was then slipped over e. The other end of this rubber tube dipped into a vessel of water. A closed screw pinchcock was then attached to the rubber tube near e and the bulb A was tilted so that its interior walls were completely wetted with the sodium hydroxide solution. This served to dry the gas somewhat and to remove any acid fumes which might be present. The pressure on the interior of the electroscope was now exhausted to about one-half atmosphere and the stopcocks closed. The capillary tubes at f and g were notched with a file and f was connected with one of the stopcocks of the electroscope by a short section of rubber tubing. The pinchcock at e was then opened, the tip of the capillary tube f was broken off inside the rubber tube, the stopcock of the electroscope was opened slightly and the air in A was drawn over into the electroscope. When the water had risen in A until it had reached the junction of the side-tube g, the pinchcock at e was closed, the tip of g was

broken off and the external air was allowed to sweep through the system of tubes until the pressure within and without the electroscope was the same. The stopcock of the electroscope was then closed and the other apparatus disconnected.

For determining the rate of leak or discharge of the gold-leaf, measurements were made of the time required for the gold-leaf to fall through a distance equal to eight divisions of the scale in the eye-piece in the microscope. The time required was recorded by means of a stop-watch divided to fifths of a second. Because of the initial rise in the activity, due to the formation of induced activity within the electroscope, the rate of leak at the end of three hours was chosen in comparing the results obtained with different minerals.

In order to determine the quantity of uranium present in the mineral under examination, the solution in the bulb B was washed out into a beaker and the quantity of uranium determined by one of the ordinary methods of analysis.

The capacities of the two final sections of the apparatus were determined by filling them with water and weighing them, and then weighing them when empty. The average capacity of A in the different experiments was about 48^{cc} and the average capacity of the rest of the apparatus was about 9^{cc}. In comparing the results obtained with different minerals it was in general assumed that the distribution of the emanation throughout the different parts of the apparatus was uniform and the volume occupied by the solution was neglected. Since the capacities of the different pieces of apparatus used were in all cases approximately the same and the volumes of the different solutions were all approximately equal, this possibly doubtful assumption would cause no serious error in the results when used for purposes of comparison.

The results obtained with eight different samples of uranium minerals are given in a table below. For decomposing the uraninites strong hydrochloric acid containing a little nitric acid was used, the gummite and uranophane were treated with strong hydrochloric acid and the carnotite was dissolved in dilute (1 : 1) nitric acid. The sample of samarskite used was obtained in a very finely divided condition by suspension in water and decantation from the coarser material. In this form it could be readily decomposed with concentrated sulphuric acid.

The samples No. 1, 2, 3 and 4 were from North Carolina, No. 5 from Branchville, Conn., Nos. 6 and 7 from Colorado and No. 8 from Saxony.

Between experiments 5 and 6 the adjustment of the electroscope became slightly altered from an accidental movement of the microscope support. A re-determination of the constant

for sample No. 1 under these conditions gave the value of the ratio as 263.

No.	Substance.	Per cent uranium in mineral.	Grams uranium taken.	Leak divisions per min.	Ratio leak to uranium.
1	Uraninite	82·5	0·1067	22·5	211
2	Gummite	66·1	0·0982	20·8	212
3	Uranophane	46·6	0·0671	12·1	181
4	Samarskite	9·8	0·0299	6·4	214
5	Uraninite	83·9	0·0994	20·6	207
6	Carnotite	18·0	0·0258	6·9	267
7	Uraninite	54·6	0·0783	19·8	253
8	Uraninite	48·5	0·0699	16·5	231

The low value of the ratio in the experiment with No. 3 was at first attributed to the fact that this material appeared to give off in the cold a greater proportion of its emanation than the other minerals of the series and that it had, therefore, not reached a state of equilibrium at the time when the emanation was measured. A more careful measurement of the proportion of emanation lost by the cold pulverized samples was made and no differences sufficiently great to explain the low value in No. 3 were obtained. Since the solution of the uranophane had gelatinized on standing in the solution apparatus, owing to the relatively high proportion of silica which the mineral contains, it was thought that this might have been the cause of the low result. Small samples of Nos. 1, 2 and 3 were, therefore, completely decomposed with acids and the resulting solutions evaporated to dryness on the water-bath. The residues were treated with dilute hydrochloric acid and the solutions thus obtained were introduced into apparatus similar to the solution tubes (fig. 2) already described, except that the lower part consisted of a single bulb only. The solutions were then sealed up and allowed to stand for thirty days. At the end of this period the bulb *A* was sealed off and the accumulated emanation transferred to the electroscope. The results thus obtained are given in the following table:

No.	Substance.	Per cent uranium in mineral.	Grams uranium taken.	Leak divisions per min.	Ratio.
1	Uraninite	82·5	0·1227	16·6	135
2	Gummite	66·1	0·0964	13·3	138
3	Uranophane	46·6	0·0686	9·8	143

It is therefore probable that the low value obtained in the first experiment with the uranophane was due to the formation of gelatinous silica. The value of the ratio stands in no direct relation to that obtained in the other series, since the adjustment of the electroscope was again different.

The chief sources of error in the method as described are due to two causes. One of these lies in the fact that the heating of the tube connecting the bulb *A* with the bulb *B* naturally warms the gases contained within them and causes a slight alteration in their relative capacities. This difficulty was avoided as much as possible by wrapping both bulbs in wet filter paper before the tube connecting them was heated. The other possible error lies in the fact that some of the minerals tested, particularly Nos. 7 and 8, contained a considerable per cent of sulphides. On treating these minerals with the aqua regia necessary to decompose them, the sulphur of the sulphides was in part oxidized to sulphuric acid and a noticeable quantity of lead sulphate separated from the solution. Although radium sulphate is quite soluble in the strong aqua regia used, it is not impossible that slight traces of this compound were carried down by the precipitated lead sulphate. This would explain the lower values of the ratios obtained with 7 and 8.

I am particularly indebted to Prof. H. A. Bumstead of Yale University for valuable assistance and advice given in connection with this research, and to Prof. S. L. Penfield of Yale University and Dr. Joseph Hyde Pratt of Chapel Hill, N. C. for most generously supplying me with the minerals used in these experiments.

Conclusions.

The quantities of radium present in the uranium minerals which have been examined are apparently directly proportional to the quantities of uranium contained in the minerals.

Since it has been suggested by J. J. Thomson and Rutherford* as very probable that radium is formed by the breaking down of the uranium atom, and if such were the case a final state of equilibrium and a definite proportion between the uranium and radium present in minerals would be expected, these results seem to be of value in furnishing experimental evidence of the actual existence of this fixed relation. It is planned to extend the work to other minerals containing a smaller per cent of uranium and to introduce certain modifications in the method which will considerably increase its accuracy.

New Haven, Conn., June 29, 1904.

* Radio-activity, Cambridge University Press, 1904.

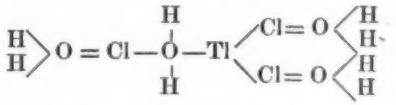
Art. XV.—*The Constitution of Hydrous Thallic Chloride;* by F. M. McClenahan.

[Contributions from the Kent Chemical Laboratory of Yale University—CXIX.]

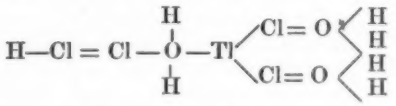
The nature of hydration and the constitution of the hydrous thallic chlorides have recently been the subject of discussion by Cushman* and R. J. Meyer.† The tetrahydrated thallic chloride $TlCl_3 \cdot 4H_2O$ is easily prepared, and Werther‡, and R. J. Meyer record the preparation of the monohydrate $TlCl_3 \cdot H_2O$, though Cushman was unable to actually isolate this salt. All assert that dehydration cannot be carried beyond the condition of the monohydrate without loss of chlorine. More recently Thomas§ has made record of the complete dehydration of thallic chloride without loss of chlorine by exposure for seventeen weeks over sodium hydroxide *in vacuo*, and ventures the opinion that there is little ground for believing that the relation of one of the molecules of water to the salt is different from that of the others. Meyer maintains that one of the chlorine atoms is not precipitated by silver nitrate and that it sustains a relationship to the complex different from the other two, so that the anhydrous salt may be represented by the symbol $(TlCl)Cl_2$. Cushman points out, however, that Meyer's use of Volhard's titrimetric method of analysis was faulty, inasmuch as the thallic salt acts as an oxidizer upon the standard potassium sulphocyanate employed to estimate the silver salt left over after precipitation of the chlorine by a standard solution of silver nitrate, and that in examinations of the filtrates from the usual gravimetric determination (by silver nitrate in presence of a sufficiency of nitric acid), no sign of incomplete precipitation of the chlorine was observed. Cushman concludes that the evidence which supports the writing of thallic chlorides as $(TlCl)Cl_2$, as well as all speculation from this point of view, falls to the ground. From experiments in which two specimens of a crystalline non-hygroscopic preparation of the tetrahydrated thallic chloride $TlCl_3 . 4H_2O$ were exposed twenty-one weeks in desiccators, the one over sulphuric acid and the other over phosphoric pentoxide, the conclusion was drawn by Cushman, that it may be taken as certain that the last fourth of the water comes off slowly

* Amer. Chem. Jour., 24, 222 (1900); 26, 505 (1901).
† Zeischer. Anorg. Chem., 32, 72 (1902).
‡ Jour. prakt. Chem., 91, 385 (1864).
§ Compt. Rend., cxxv, 1051 (1902).

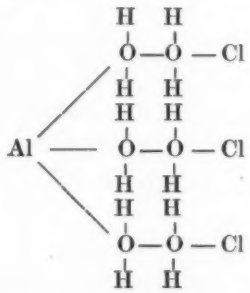
accompanied by chlorine, but that evidence for a definite monohydrate stage is slight. Cushman proposes to account for the relations of water of crystallization in salt complexes upon the hypothesis that oxygen can be quadrivalent and for the tetrahydrated thallic chloride suggests the symbol



and for the crystalline compound obtained by Meyer when the preparation of the hydrous thallic chloride is attempted in presence of hydrochloric acid the related symbol

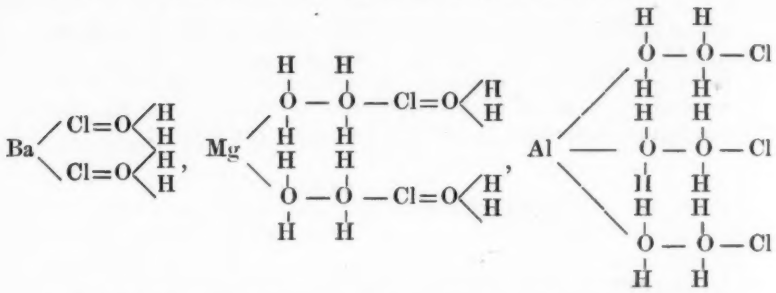


For the molecule of hydrous aluminium chloride Cushman suggests that the water is held within the complex in a manner suggested by the symbol



which brings out the observed fact that water cannot be broken from the molecule without formation of hydrogen chloride, at least in the primary action. The application of Cushman's hypothesis of the quadrivalent linking of oxygen in hydrous salts has been made in a former paper from this laboratory* to the comparative phenomena observed when certain typical hydrous salts, $BaCl_2 \cdot 2H_2O$, $MgCl_2 \cdot 6H_2O$, and $AlCl_3 \cdot 6H_2O$ are dehydrated in air and in an atmosphere of hydrogen chloride. It was shown that the phenomena of these salts are in harmony with the assumption of the symbols

* Gooch and McClenahan: this Journal, xvii, 365 (1904).



in which the molecules of water which may be expelled easily by heat without loss of hydrogen chloride, and at the same rate in air and in hydrogen chloride, are placed outside the chlorine of complex, while those molecules of water which are removed with more difficulty and at a rate affected by the environment, air or hydrogen chloride, are placed inside the chlorine. The suggestion was made that the influence of hydrogen chloride as compared with that of air upon molecules outside the complex is insignificant, while upon molecules of water within the complex the effect may appear variably, according to conditions, (1) in a retardation of dehydration and greater stability of the whole complex, or (2) in acceleration of dehydration with formation of the anhydrous chloride or with hydrolysis implying loss of hydrogen chloride and formation of a residual hydroxide or oxide.

In the present paper, the changes which the thallium chloride $TlCl_3 \cdot 4H_2O$ undergoes when heated in air and in hydrogen chloride have been studied and discussed in relation to the hypothesis of quadrivalent oxygen.

Experimental Part.

Thallous nitrate was dissolved in distilled water and the thallium precipitated as the chloride by means of hydrochloric acid. The precipitate was filtered on asbestos and washed thoroughly of all hydrochloric acid. It was then transferred to a test tube and chlorinated until the last traces of the solid were gone. The solution was evaporated to incipient crystallization and allowed to stand until the clear crystals of thallic chloride appeared. These were removed, dried by means of filter papers, desiccated for a brief period and a sample taken for analysis.

The chlorine in the salt was estimated by the usual silver chloride method, making sure of enough nitric acid. The thallium was estimated as thallous sulphate.* A weighed por-

* Browning : this Journal, ix, 137 (1900).

tion of the salt was transferred to a crucible and a few drops of sulphuric acid added. This was evaporated and the temperature was raised to approximately 200° C. The crucible was cooled in a desiccator and weighed, the weight of the residue was taken to be the acid thallous sulphate. The crucible was again heated and the temperature was raised to that of dull redness. After a suitable period of cooling it was again weighed, and the weight of the residue reckoned as the normal thallous sulphate.

Composition of the Salt.

PREPARATION I.

	Found.	Theory for $TlCl_3 \cdot 4H_2O$.
Thallium	53·74	53·36
Chlorine	27·81	27·80
Water (by difference)	18·45	18·84
	100·00	100·00

Weighed portions of this salt were transferred to weighed porcelain boats which were placed in combustion tubes passing through a water bath after the fashion of boiler tubes. A slow current of dry air was sent through the tubes kept at 100°. At the end of an hour the boat was removed and weighed. The residue in the boat was dissolved in water containing nitric acid and the chlorine estimated by precipitation and weighing as silver chloride. The calculated composition of the salt is given below.

Dehydration of $TlCl_3 \cdot 4H_2O$ at 100°, in one hour.

Weight of salt taken. grms.	Loss. grms.	Per cent. loss.	Chlorine in residue. grm.	Chlorine in residue.	Loss of Chlorine. Per cent.
0·1572	0·0282	17·94	0·0430	27·36	·45
0·1615	0·0298	18·45	0·0447	27·68	·13
0·2252	0·0402	17·85	0·0620	27·55	·26
0·2221	0·0396	17·83	0·0614	27·65	·16
0·1343	0·0237	17·65	0·0371	27·63	·18
0·1719	0·0308	17·92	0·0473	27·51	·30

Obviously the hydrolytic decomposition during the process of dehydration at 100° is very small in the case of the hydrous thallium chloride $TlCl_3 \cdot 4H_2O$. By the passage of dry air at 100° over the salt for an hour, nearly anhydrous thallic chloride was obtained, with small loss of chlorine, averaging about 1 per cent of the entire amount in the original salt. The anhydrous residue was crystalline and sparkling in the sunlight, but highly hygroscopic.

Preparation II.

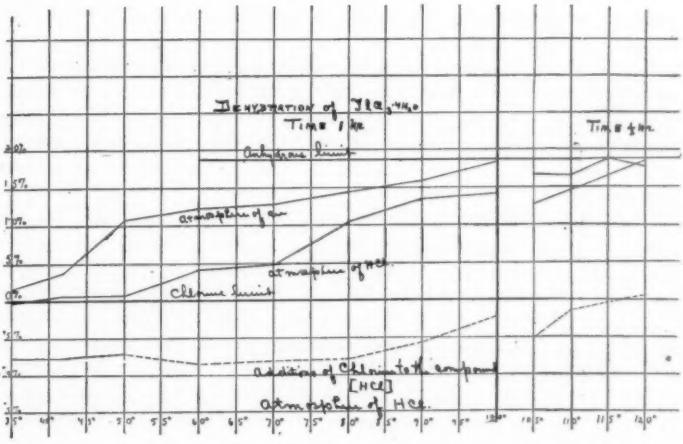
Number.	Weight heated.		Change of Weight when heated.				Chlorine in Residue.				Variation in Chlorine from theoretical constitution of salt.		Calculated gain or loss of HCl.		Loss of Water.		Temperature.
	In air. grm.	In HCl. grm.	In air. grm.	In HCl. grm.	In air. %	In HCl. %	In air. grm.	In HCl. grm.	In air. %	In HCl %	In air. %	In HCl. %	In air. %	In HCl. %	In air. %	In HCl. %	
1	0·1534	0·1777	−0·0025	+0·0148	− 1·63	+ 8·33	0·0421	0·0628	27·44	35·34	−0·36	+7·54	−0·35	+7·75	− 1·28	− 0·58	35°
2	0·1664	0·1889	−0·0065	+0·0135	− 3·91	+ 7·15	0·0466	0·0671	28·12	35·52	+0·32	+7·72	+0·33	+7·94	− 4·24	− 0·79	42°
3	0·1775	0·1825	−0·0190	+0·0118	−10·70	+ 6·40	0·0508	0·0637	28·62	34·90	+0·82	+7·10	+0·84	+7·30	−11·54	− 0·90	50°
4	0·1243	0·1416	−0·0153	+0·0063	−12·31	+ 4·45	0·0348	0·0514	28·00	36·29	+0·20	+8·49	+0·20	+8·73	−12·51	− 4·28	60°
5	0·2002	0·2086	−0·0253	+0·0065	−12·64	+ 3·12	0·0562	0·0730	28·07	35·00	+0·27	+7·20	+0·28	+7·43	−12·92	− 4·31	70°
6	0·1354	0·1290	−0·0194	−0·0034	−14·33	− 2·64	0·0378	0·0461	27·92	35·74	+0·12	+7·94	+0·12	+8·17	−14·45	−10·81	80°
7	0·1543	0·1594	−0·0245	−0·0122	−15·88	− 7·65	0·0433	0·0533	28·06	33·44	+0·26	+5·64	+0·27	+5·86	−16·15	−13·45	90°
8	0·1537	0·1617	−0·0284	−0·0195	−18·48	−12·06	0·0430	0·0482	27·98	29·81	+ ·18	+2·01	+0·18	+2·07	−18·66	−14·13	100°

Preparation III.

9	0·1683	0·1472	−0·0284	−0·0112	−16·88	− 7·61	0·0477	0·0485	28·34	32·95	+0·54	+5·15	+0·55	+5·29	−17·43	−12·90	105°
10	0·1800	0·1442	−0·0300	−0·0189	−16·66	−13·11	0·0503	0·0423	27·94	29·33	+0·14	+1·53	+0·14	+1·57	−16·80	−14·68	110°
11	0·1384	0·1060	−0·0260	−0·0169	−18·79	−15·94	0·0380	0·0300	27·46	28·30	−0·34	+0·50	−0·35	+0·51	−18·44	−16·45	115°
12	0·1157	0·1426	−0·0202	−0·0263	−17·46	−18·44	0·0318	0·0385	27·59	27·00	−0·21	−0·80	− ·21	−0·82	−17·25	−17·62	120°

In the series of experiments next recorded, another preparation of the hydrous thallic chloride was dehydrated at various fixed temperatures in air or in hydrogen chloride, the loss of weight after a definite interval was noted, and the chlorine determined gravimetrically in the residues. The details of the experiments are given in the following statement. The course of dehydration in air and in hydrogen chloride and the action of hydrogen chloride upon the salt are represented in the diagram.

It is to be noted in the first place that although the preliminary analysis indicated a composition of the preparation of the hydrated thallic chloride used in these experiments, the close correspondence with the symbol $TlCl_3 \cdot 4H_2O$, there is an apparent slight gain in the chlorine contents of the chloride



when heated in air nearly throughout the series. This is probably due to an incipient dehydration of the salt before it was weighed out for the work, and the slight deficiency in the total amount of water generally found points in the same direction. Inasmuch, however, as it is a comparison of the behavior of the salt in air with its behavior in an atmosphere of hydrogen chloride which is to be studied, this trifling variation from normal constitution is not important.

It is manifest that the hydrous chloride takes on hydrogen chloride in some degree in an atmosphere of that gas at all experimental temperatures below 100°, and this is without doubt due to the tendency of the salt to form under the conditions of the chlorthallic acid observed by Meyer. At temperatures below 50°, the loss of water in an atmosphere of hydrogen

chloride is small, while the addition of hydrogen chloride is relatively considerable. For this range of temperature in an atmosphere of hydrogen chloride, the constitution of the salt corresponds to the symbol of the chlorthallic acid, $TlCl_3 \cdot 3H_2O \cdot HCl$, with some of the liberated water retained by the hygroscopic compound. At 60° and 70° this hygroscopic water volatilizes and the substance has, approximately, the composition represented by the symbol $TlCl_3 \cdot 3H_2O \cdot HCl$; at 80° the composition suggests the formation of some $TlCl_3 \cdot H_2O \cdot HCl$; while at 90° hydrogen chloride with more water is leaving the salt, and at 100° after an hour's heating, and at 110° after a half hour, the composition corresponds to a mixture of salts, $TlCl_3 \cdot H_2O \cdot HCl$ and perhaps some $TlCl_3 \cdot 3H_2O \cdot HCl$ with $TlCl_3 \cdot H_2O$. At 115° after a half hour the hydrogen chloride is nearly gone and the further dehydration of $TlCl_3 \cdot H_2O$ has begun; and at 120° the product is practically the anhydrous salt, $TlCl_3$, slightly reduced to the thallous-thallic chloride. When a comparison is instituted between the results obtained by heating the salt in air to temperatures above 100°, where the chlorthallic acid is breaking down, and those obtained under similar conditions of temperature in hydrogen chloride, it is obvious that dehydration of the salt $TlCl_3 \cdot H_2O$ is inhibited by an environment of hydrogen chloride.

Reverting now to Cushman's diagram* of the results obtained by long exposure of the hydrated thallic chloride, $TlCl_3 \cdot 4H_2O$, in desiccators at the ordinary temperature, it appears that two molecules of water disappeared from the salt in the course of a week, that the third molecule required for its removal five weeks, and that the fourth molecule vanished only after fifteen weeks more. The general order of the phenomena is in accord with the observations recorded above for the behavior of the salt at higher temperatures during the interval of an hour.

As appears from Cushman's diagram, the preparation of the dehydrated chloride, $TlCl_3 \cdot 2H_2O$, should be very easy. This salt was therefore made the starting point of a series of experiments upon the rate of dehydration in air. A new sample of the chloride, $TlCl_3 \cdot 4H_2O$, was crystallized out and this was desiccated over calcium chloride for three days, until upon analysis the residue was found to have the constitution shown by the symbol $TlCl_3 \cdot 2H_2O$. In this analysis the chlorine was determined, as usual, in the form of silver chloride, precipitated in presence of a sufficiency of nitric acid, and the thallium was estimated as the light yellow thallium chlorplatinate precipitated by chlorplatinic acid from the solution of the thallous salt reduced by sulphur dioxide and weighed on asbestos.

* Loc. cit.

Composition of the Salt.

	Found. I.	Found. II.	Mean.	Theory for $TlCl_3 \cdot 2H_2O$.
Thallium	59·18	59·24	59·21	58·91
Chlorine	30·77	30·72	30·74	30·70
Water (by difference)			10·05	10·39
			100·00	100·00

Portions of this salt were submitted to dehydration in air in the manner previously described, the boats holding the substance being heated in the tube-bath, generally for intervals of fifteen minutes, and then cooled in a desiccator and weighed. The data of these experiments are shown in the following table and diagram:

Dehydration of $TlCl_3 \cdot 2H_2O$, in Air.

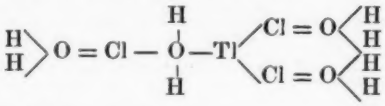
Weight taken. grm.	Loss of Weight. ¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	¼ hr.	½ hr.	2 hrs.	Chlorine loss. %	Water loss. %
0·2471 grm.	0·0097	0·0134	0·0160	0·0197	0·0221	0·0243	0·0250	0·0255	0·0269	0·0273	....	....
Per cent.	3·92	5·42	6·48	8·00	8·94	9·88	10·12	10·32	10·89	11·05	0·51	10·54
0·3441 grm.	0·0191	0·0248	0·0266	0·0276	0·0308	0·0345	0·0358	0·0371	0·0382	0·0390	....	....
Per cent.	5·55	7·21	7·73	8·02	8·95	10·03	10·40	10·78	11·10	11·33	0·54	10·75
0·3083 grm.	0·0209	0·0241	0·0263	0·0283	0·0302	0·0335	....	....	....	....	....	....
Per cent.	6·78	7·82	8·53	9·18	9·80	10·87	....	....	....	....	0·50	10·37
0·3081 grm.	0·0168	0·0221	0·0237	0·0256	0·0281	0·0306	0·0324	....	....	....	....	....
Per cent.	5·45	7·17	7·69	8·31	9·12	9·93	10·52	....	....	....	0·61	9·91
0·2500 grm.	0·0197	0·0217	0·0235	0·0254	0·0264	0·0279	....	....	....	....	....	....
Per cent.	7·88	8·68	9·40	10·16	10·56	11·16	....	....	....	....	0·45	10·71
0·2250 grm.	0·0177	0·0192	0·0203	0·0221	0·0228	0·0235	....	....	....	....	....	....
Per cent.	7·87	8·53	9·02	9·82	10·13	10·45	....	....	....	....	0·51	9·94

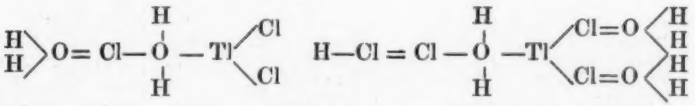
The residues remaining after heating were treated with water, the small amounts of thallo-thallic chloride found in every case and indicating the slight decomposition of the thallic chloride were dissolved by nitric acid, and the combined chlorine was precipitated as silver chloride. The difference between the chlorine thus found and the chlorine of the original salt is tabulated as "chlorine lost" in the process of dehydration. The loss of water was computed as the difference between the total loss observed and the hydrogen chloride corresponding to the chlorine lost. From these results it is obvious that the salt of constitution corresponding to the symbol $TlCl_3 \cdot 2H_2O$ loses the first molecule of water (5·2%) with comparative ease, while the second molecule disappears gradually on prolonged heating.

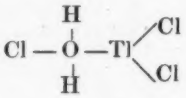
Taking into consideration all the observed phenomena which have been described, it appears that the water in the hydrous thallic chloride $TlCl_3 \cdot 4H_2O$ is held in the complex in three different ways, and that the relation may be reasonably expressed by the symbol $TlCl_3 \cdot H_2O \cdot H_2O \cdot 2H_2O$, the fourth molecule of water being removed less easily in an atmosphere of hydrogen chloride than in air. We have, therefore, the sequence of changes during dehydration represented by the following symbols:

In air.	In HCl.
$TlCl_3 \cdot H_2O \cdot H_2O \cdot 2H_2O$	$TlCl_3 \cdot H_2O \cdot H_2O \cdot 2H_2O$
$TlCl_3 \cdot H_2O \cdot H_2O$	$TlCl_3 \cdot H_2O \cdot HCl \cdot 2H_2O$
$TlCl_3 \cdot H_2O$	$TlCl_3 \cdot H_2O$
$TlCl_3 \cdot$	$TlCl_3 \cdot$

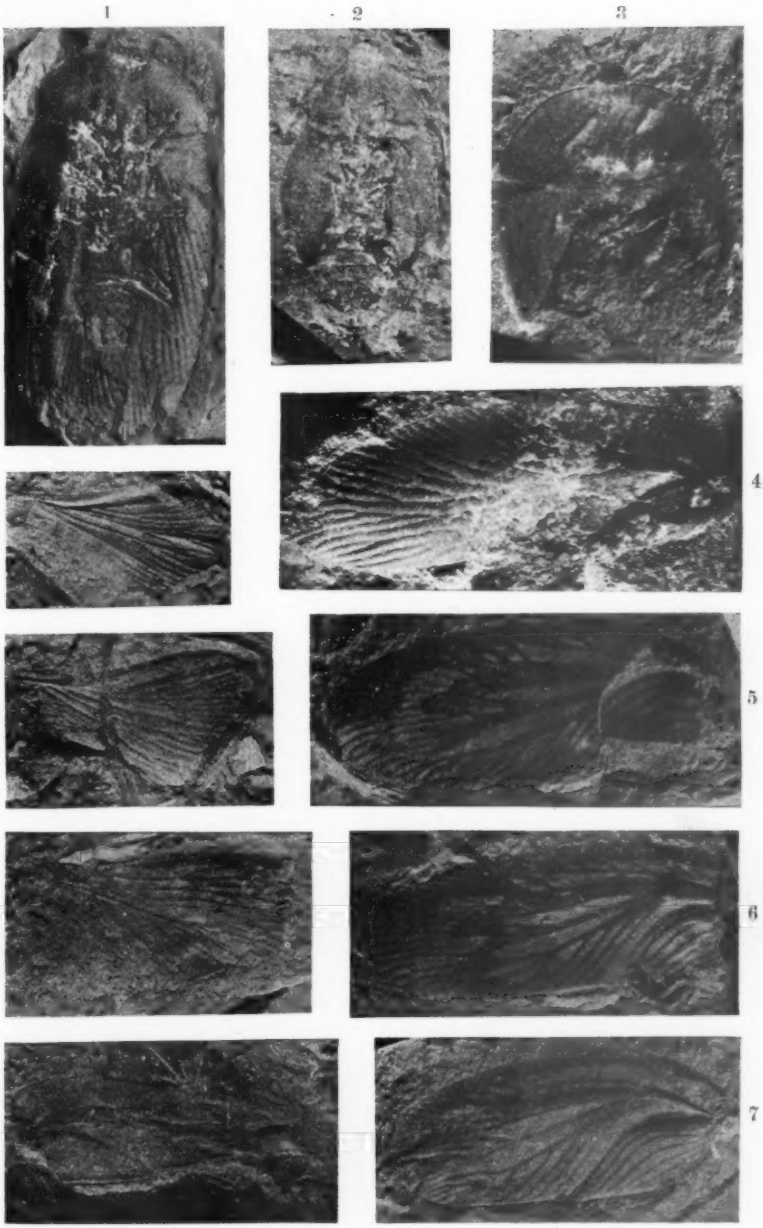
These symbols and the phenomena which they cover may be represented upon the hypothesis of quadrivalent oxygen by Cushman's symbol and its derivatives.







The author wishes to express his appreciation of the kind advice of Prof. F. A. Gooch in the preparation of this paper.



PALEOZOIC COCKROACHES.

ART. XVI.—*A Study of the Structure of Paleozoic Cockroaches, with Descriptions of New Forms from the Coal Measures;** by E. H. SELLARDS. (With Plate I and thirty-seven figures in the text.)

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Thorax. Legs. Cerci.
Front wings. Abdomen. Development.

Classification and Description of Paleozoic Cockroaches.
Description of genera and species, including nymphs.
Hind wings not in connection with the front wings.

General Considerations.

Introduction.

THE well-known habits of many species of cockroaches, their abundance, and comparatively generalized structure have made them familiar insects and favorite objects of study. They are a characteristic and easily recognized group, separated from all other insects by a number of important structural differences. The body is flat and carried close to the ground. Progression is by a rapid scurrying motion. The tergum of the first thoracic segment, or pronotum, is large, broad, and typically more or less shield-shaped, forming a shelter under which the small flat head can be more or less completely withdrawn. The anal area of the front wing is distinctly marked off by a strong furrow. In recent species the abdomen of the female has undergone considerable modi-

* A paper prepared in the laboratory of paleontology, Yale University Museum, and constituting part of a thesis presented in May, 1903, to the faculty of the Graduate School of Yale University for the Degree of Doctor of Philosophy. As published here, it has been found necessary to omit from the systematic part of the paper, as originally prepared, descriptions of some of the new species, with the expectation that later these will be described elsewhere. The structural and general part of the paper, however, remains unchanged, except for the addition of the brief discussion of the classification of Paleozoic cockroaches, and a life-size restoration of the large cockroach *Archoblattina Beecheri* Sellards.

fication as a result of a specialized arrangement of the reproductive parts. A double fold in the ventral integument forms a characteristic genital pouch, bounded in front and above by the eighth and ninth and perhaps a vestige of the tenth sterna, and below by the enlarged seventh. The main function of this pouch is to retain the egg case while the eggs are being placed in it, and in some species during the period of incubation. The ovipositors have become very much reduced and adapted to serve the specialized function of guiding the eggs into the egg case. The terga of both male and female have also become more or less reduced. As will be seen from the present study, the abdomen and ovipositor, as well as the front and hind wings of the paleozoic cockroaches, are in important respects more generalized than in their living descendants.

Historical Résumé.—The cockroaches of the paleozoic have been known heretofore for the most part from the wings only. Being farther removed from the organic juices of the decaying body, the wings stand a better chance of preservation, especially the more or less coriaceous and resistant tegmina. The body, on account of the large amount of organic matter present, decays more rapidly, and no doubt often served as food for the numerous animals inhabiting the water at that time; hence is much more rarely preserved. The chitinous nature of the wings, on the contrary, renders them comparatively resistant. Moreover, as suggested in an earlier paper, it is probable that some of the small batrachians, dragon flies, or spiders, found in the same deposits, may have acquired the habit of biting off and rejecting the wings, as do the recent dragon flies, bats, and some arachnids. The detached wings are, moreover, readily carried by currents of water into places where permanent deposits are accumulating. The distinction between the paleozoic and recent forms was originally based almost entirely on differences in the front wings.* Some additional knowledge of the structure of other parts of the body has since accumulated from the studies of a considerable number of investigators, among whom are Scudder, Brongniart, Woodward, Deichmüller, Goldenberg, Geinitz, Germar, and others. After the tegmina, the pronotum is the part of the body most commonly preserved, and has been described in connection with the wings by several authors, especially by Scudder and by Brongniart. The habit of concealing the head beneath the pronotum was evidently already developed in paleozoic time, and it is usually rare that any portion of the head is apparent. Woodward detected parts of the head on *Etoblattina Peachii* and *Leptoblattina exilis*, on both of which

*Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 29, 1879.

the top of the head and the line dividing the epicranium may be seen.* But previous to the present study, the eyes and antennæ had not been observed. Surprisingly few hind wings have been described. Brongniart has figured some good ones without description.† Goeppert in his Fossile Flora der permischen Formation, Plate 28, figures under the specific name *Blattina neuropteroides*, what is evidently a small hind wing. In Bulletin 124 of the U. S. Geological Survey, Scudder has described several additional hind wings and reviewed those that had come to his notice up to that time. The legs, with the exception of the tarsus and basal elements, have previously been described in a general way. Deichmüller's *Etoblattina flabellata*, var. *Stelzneri*, preserves on the type specimen the outlines of the coxæ, trochanters, femora, and tibiæ.‡ The *Anthracoblattina sopita* Scudder (*Blattina didyma* Geinitz) shows the femur and tibia of the second pair of legs and the femur, tibia, and a part of the tarsus of the third pair.§ Indications of legs have been noticed by various authors on a number of specimens.

The sword-shaped ovipositor first noticed by Brongniart‖ is one of the most striking differences between paleozoic and recent cockroaches. The presence of the ovipositor can now be verified from American material, and its structure more fully described. Woodward had previously recognized the presence of cerci on these fossils and distinguished the ten abdominal terga, observing that the eighth and ninth were not reduced as in the living forms. The writer in a short paper appearing in the April, 1903, issue of this Journal, gave some additional structural characters of paleozoic cockroaches. Mr. A. L. Melander in the February-March number of the Journal of Geology, 1903, published, however, during the month of April, figures an additional cockroach from Mazon Creek.

Localities and Collections.—Almost all the American material preserving the structure of the body has come either from the Middle or Lower Coal Measures at Mazon Creek, Illinois, or from the Upper Coal Measures at Lawrence, Kansas. In the spring of 1901, the writer discovered the presence of fossil insects among plants collected by Mr. Martin and himself, from the Haverkampf farm near Lawrence.¶ Subsequent

* Geological Magazine, Decade 3, vol. iv, p. 49, 1887; ibid., p. 433.
† Histoire des Insectes Fossiles, atlas, pl. 47, 1893.
‡ Sitzungsb. Gesellsch. Isis, vol. xxxiv, p. 34, 1882.
§ Geinitz, Neues Jahrb. für Min., pp. 4–5, 1875.
‖ Comptes Rendus, Feb. 4, 1889, p. 252; Hist. des Ins. Foss., p. 417, 1894.
¶ A single specimen from a nearby locality in the same formation, found many years earlier by Mr. Joseph Savage, was sent to Lacoe and subsequently described by Scudder as *Etoblattina occidentalis* (Mem. Boston Soc. Nat. Hist., vol. iv, No. 9, p. 410, pl. 32, fig. 4, 1890).

visits to the locality resulted in the discovery of as many as fifty specimens, indicating the comparative abundance of the insects. Later in the summer the Kansas Geological Survey sent a party into the field and obtained in all over two hundred specimens, among them a considerable number of immature forms, or nymphs, or more properly in most cases the sheddings or moults of nymphs. In the fall of the same year, Professor C. E. Beecher very generously placed at the writer's disposal for study the Yale collection of paleozoic cockroaches, especially rich both in nymphs and in adults preserving structural characters. During the past two summers the writer has almost doubled the original number of specimens from the Lawrence Shales, the later collections containing especially instructive nymphs. More recently, Mr. Charles Schuchert has very kindly sent for comparison and study the cockroaches from Mazon Creek contained in the Lacoe collection of the United States National Museum. Mr. L. E. Daniels, through Mr. Schuchert, has loaned from his private collection several specimens from the Mazon Creek locality. During the summers of 1902 and 1903 the writer also obtained a collection of over two thousand fossil insects from a new locality in the Permian of Kansas. Cockroaches in the Kansas Permian are very much in the minority as compared with other families. A considerable number, however, were secured, and these, although not described in detail, have been useful in comparing with those from lower horizons.

Acknowledgments.—The results of an investigation of this kind depend to a considerable extent upon the success of developing and cleaning the fossils. This is especially true of the Mazon Creek specimens, in which the contrast between fossil and matrix is often slight, and the indurated nodules are difficult to work. It was the writer's good fortune in this study to have the advantage of the direction and guidance of the late Professor C. E. Beecher, whose skill in preparing and wide experience with fossils made his suggestions of inestimable value. Moreover, not a little of the skill and ingenuity for which this master of paleontological technique was famous had been expended, with the usual excellent results, on several of the Mazon Creek specimens of the Yale Museum before the collection came into the writer's hands for study. It is also a pleasure to acknowledge indebtedness to Dr. S. W. Williston, Mr. Charles Schuchert and Mr. L. E. Daniels. Dr. Williston encouraged the development of the Lawrence locality, and made the collections belonging to the University of Kansas accessible for study. Mr. Schuchert has contributed not a

little by supplying important types from the National Museum collection. The specimens sent by Mr. Daniels have been of the greatest interest, as adding to the collections from the famous Mazon Creek locality.

Nomenclature used in dealing with the Nymphs.—In attempting the study of a collection of fossil cockroaches, including numerous specimens in the nymph stages, the investigator is met at the outset by the perplexing question of nomenclature. It will rarely be found possible to identify all the nymphs with their respective adult species. When only a few nymphs are to be dealt with, no great inconvenience results from simply referring them to their tribe, or genus, if possible, as immature forms. But when, as in the present instance, a large number are at hand which separate themselves naturally into specific groups, some means of designating a group as a whole becomes practically necessary. Accordingly, in a few instances specific names have been retained or proposed for well-defined species as a means of reference until their connection with adults can be established. Inasmuch as it is difficult, if not impossible, to distinguish the closely related genera of the tribe Mylacridæ in the nymph condition, it has been thought admissible to use the type genus *Mylacris* in a somewhat extended sense, to include the nymphs of the tribe. *Etoblattina* is used in the same way to some extent for the Blattinariæ, although this tribe is more varied, and generic characters seem to appear earlier.

Terminology of the Veins of the Wing.—The system of designating the veins used in the description of species in the present paper is that developed by Redtenbacher and now fortunately coming into general use in entomology. This recognizes in the typical wing five main veins, aside from those of the anal area. It is much to the credit of this system that it is readily applicable to the wings of the simple and comparatively unspecialized insects of the paleozoic. A great deal has been done in recent years to establish the essential unity of the plan of structure of the wing and to discover the homologies of the main veins in the different orders of insects, with the result that many entomologists are now convinced that all winged insects have descended from a common winged ancestor. The complicated arrangement of the veins, so difficult to decipher in the wings of many living adult insects, becomes more and more simple as the phylum is traced toward its point of origin. As paleontological evidence becomes more complete, the steps in the differentiation of the wing can be more closely followed. Inasmuch as the terminology of the veins and their

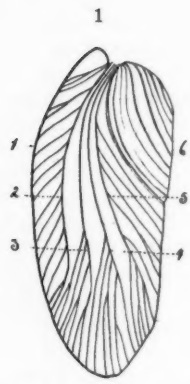


FIGURE 1. — *Gerablattina arcuata* Sellards.

areas used in this paper is different from that proposed by Heer and employed heretofore in the literature of American paleozoic insects, it has been thought advisable to introduce a sketch of the wing of a typical member of the Paleoblattidæ, giving Redtenbacher's and Heer's names in parallel columns.

Terminology of the wing veins as developed by Redtenbacher.	Terminology of the wing veins applied by Heer to cockroaches.
1. Costa.	Marginal.
2. Subcosta.	Mediastinal.
3. Radius.	Scapular.
4. Media.	Externomedian.
5. Cubitus.	Internomedian.
6. Anal veins.	Anal veins.

Structure of Paleozoic Cockroaches.

Head.—The head is small, flattened, and capable of being withdrawn partly or entirely beneath the pronotum. The part most commonly seen is the top, or top and front. The sutures dividing the parts of the head are often discernible. The eyes are placed well up toward the top. Their shape is obscured by crushing, but they were large and apparently elongate or reniform. The frons or clypeus posterior is occasionally recognizable (Text-figure 9). The mandibles have not been observed. Supposing them to have been as firmly chitinized as at present, their absence where more delicate structures are preserved is unexpected, and suggests the possibility that the early cockroaches may have fed on soft vegetation, and have had less strongly chitinized mandibles than their omnivorous descendants. The antennæ are long, slender, and many jointed. They are enlarged at the base and united to the head by a circular socket-like attachment (Text-figures 4 and 19).

Thorax.—The segments of the thorax, as in living generalized insects, are not fused or closely united. The pronotum presents considerable variation in shape in the different genera and species, and goes through a regular series of changes during the growth of the individual. At first the posterior border is straight, the lateral angles pointed, and in the Mylacridæ directed backward. As growth progresses the corners become less acutely pointed, then rounded, and the posterior border fuller. The pronotum of the adults of the tribe Mylacridæ is always proportionately broad, but with a rounded posterior border. Among the Blattinariæ the modification progresses

farther, many of the adults of this tribe having an almost circular pronotum. In describing *Etoblattina Peachii* Woodward (*loc. cit.*) refers to a prominent notch in the pronotum. From the illustration given it would seem that the notch was not natural, but caused by the decay and more rapid erosion of the pronotum directly over the head, a feature not uncommon in similar iron-stone nodules from Mazon Creek (Text-figure 7).

Front Wings.—The front wings have been thoroughly studied by Scudder and others, and their distinctive and primitive characters pointed out. The four principal veins of the front wings,—subcosta, radius, media, and cubitus, are distinct to the base. In most living forms two or more of the main trunks disappear by fusion with the adjoining veins, although all four can be seen in their original position in the living nymphs (Text-figure 37). The anal area was well marked off as early at least as the middle of the Carboniferous, but the anal veins, as Goldenberg and Scudder have noted, end with rare exception on the inner border, while, as a rule, among living forms the anal veins end on the furrow. The tegmina were for the most part less coriaceous than those of living forms. Well-developed cross veins are comparatively rare.

Hind Wings.—The hind wings are thinner and more delicate than the front and are much less often preserved. They do not fold longitudinally as do the hind wings of living cockroaches. Cross veins as far as known are absent. The anal area did not present so great a spread as that of modern cockroaches, and, as Scudder has said, does not seem to have been plaited as in almost all modern forms. The costa is submarginal and occasionally gives off one or two superior branches. The veins of this wing are more uniformly developed than in the hind wings of most modern cockroaches. Strength is obtained as in living forms by a subcostal fold. The costal border is nearly straight or a little concave near the base. The inner border is full and well rounded, making the wing broad in proportion to its length (Text-figures 33–36, and Figures 8–10 of Plate I).

Legs.—The legs are not uncommonly preserved, showing either as impressions through the integument or projecting from beneath the body. The second pair is somewhat larger than the first, and the third longer than the second, indicating that progression was by running. The tibia, of some forms at least, was spinous (Text-figures 8 and 14). The femur, on the contrary, was probably smooth, since well-preserved femora show no indications of spines. The first joint of the tarsus seems to have been comparatively long. The number of segments is not distinct on any specimen at hand, but the tarsus was terminated by a claw (Text-figure 23).

Abdomen.—Ten terga are to be seen on the abdomen of both male and female. The projecting edges of the terga are well developed from the third or fourth to the ninth. The tenth tergum is smaller and more or less rounded. The two cerci project from beneath it. The seventh, eighth, and ninth terga are well developed, presenting in this respect a marked contrast to the common existing cockroaches, among which the corresponding terga in both male and female are very much reduced and partly covered by the seventh, even in the later nymph stages. More difficulty is encountered in the study of the sterna. They are seen either in outline through the terga, or, the terga having been removed, are viewed directly. The first sternum, which was doubtless, as in living forms, much reduced and imperfectly chitinized, has not been observed. The third to the ninth can be seen lying beneath their respective terga on a few individuals, presumably males. The seventh sternum of the female is enlarged, rounded, and lies beneath the seventh, eighth, and a part of the ninth terga. The relative position of the parts can be determined from several specimens (Figure 12). The position of the eighth and ninth sterna of the female has not been determined. As Brongniart has suggested (Hist. Ins. Foss., p. 417), the habit of depositing the eggs within an egg case was probably not common at that time. Many of the species doubtless deposited their eggs singly either on the ground or underneath the bark of trees or within small stems. Certain paleozoic ferns in immediate association with cockroaches have been observed to present a row of slits along the rachis, which appear to have been made by such an organ as the ovipositor of the Paleoblattidæ, and, as has been stated in an earlier paper, are indeed strikingly similar to scars seen on the stem of the common *Amorpha fruticosa* (false indigo) and said to be made by katydids.* Nevertheless some genera may have acquired the habit of putting the eggs within egg cases as early as the latter part of the Carboniferous. The writer has recently obtained a fossil from the Upper Coal Measures of Kansas which has a striking resemblance to the egg cases of modern cockroaches (Figure 25).

Ovipositor.—The ovipositor is present on several specimens. The parts of this organ in one very young individual of *Etoblattina mazona* (Figure 11) have apparently not yet united, and present a striking similarity to the early stages in the development of the ovipositor in the Locustidæ, as

* A description of the scars found on the rachis of *Tæniopteris* Brongniart and *Glenopteris* Sellards has been given by the writer in the Kansas Univ. Quart., vol. ix, p. 184, July, 1900; ibid., vol. x, pp. 9–12, Jan., 1901. Similar scars on *Tæniopteris* from West Virginia are described by Fontaine and I. C. White (Perm. Flora, p. 92); and on *Macrotæniopteris* from Virginia by Fontaine (Mon. VI, U. S. G. S., Older Mes. Flora, p. 18, 1883).

figured for *Locusta* by Dewitz.* From this specimen it appears that the ovipositor is composed of probably three pairs, of which the inner is the smallest. In the later stages when the three pairs have become united the component parts are indicated by a groove down the center (Figure 13).

Cerci.—The cerci, which are not uncommonly preserved, vary a good deal in length in the different genera and species, from very long as in *Etoblattina juvenis* to a moderate length as in *E. mazona* and other species. Usually the cerci are directed obliquely to the body; occasionally, however, they stand at right angles, as in *Mylacris anceps*.

Development.—The development, as shown by the numerous nymphs of the collections representing various stages in the ontogeny of single species, is, as in modern cockroaches and other Orthoptera, direct, the young resembling the adults and growth taking place by a succession of moults.

Classification and Description of Carboniferous Cockroaches.

Order *Orthoptera.*

The Carboniferous cockroaches are quite generally recognized as constituting a group of family rank, the Paleoblattidæ, in contradistinction to the modern family Blattidæ. In the disposition of the Paleoblattidæ under the larger divisions, there is, unfortunately, no such uniformity of usage. They are, by some, separated entirely from their modern descendants and included along with other insects in a distinct order, the Paleodictyoptera. By others they are referred directly to the Orthoptera. This diversity of classification, affecting all the paleozoic insects, results not so much, perhaps, from any disagreement as to the essential facts presented, so far, at least, as cockroaches are concerned, as from a difference in the viewpoint from which the facts are interpreted and applied.

The chief contention for the establishment of the order Paleodictyoptera, as expressed by Professor Samuel H. Scudder, is that paleozoic insects as a whole are more closely related among themselves than to their (known) descendants of mesozoic and later times,—a classification in which emphasis is given to the interrelation of contemporaneous but diverging groups, or the lateral relation of organisms, rather than to the lineal or phylogenetic relation in time of particular lines of development. The question of the classification of paleozoic insects in general is not within the range of this paper and will not be touched upon here, except in so far as the principles applied affect the disposition of the Orthoptera as represented by the cockroaches. The gap between the Carboniferous

* Zeit. für wiss. Zool., vol. 25, p. 176, pl. 12, figs. 1–11, 1875.

representatives of modern Orthoptera and the early forms of other orders is, even at that time, an actual one, indicating a considerable divergence in the phylogenetic lines. On the other hand, the apparent break between Carboniferous and later Orthoptera is accidental and due to the fact that not all of the intermediate forms have been preserved, or if preserved have not yet been found. The object of schemes of classification, as is universally conceded, is to express, as far as possible, phylogenetic relations. Following this leading principle, any natural group of organisms should be recognized as extending back in time until a point is reached at which that group coalesces with a group or groups of coördinate rank, or unites with the parent stock. It may often be a matter of difficulty, owing to the imperfect geological record and other causes, to determine the exact point of origin of a group from an ancestral stock. In the case of the Orthoptera, however, the evidence at hand seems conclusive that the order as a distinct phylum is recognizable well into or beyond the Carboniferous. Not only does the body structure of these early forms present the essential features of the Orthoptera, but the development, as is here shown, is in entire agreement with that of modern forms, the young resembling the adults and growth taking place by a succession of moults during which the wings appear gradually.

Super-Family *Blattacea.*

The cockroaches of the Carboniferous, as shown by the foregoing detailed account, are closely related to those of mesozoic and later times. The early forms present not a few generalized characters, such, for example, as the protruding ovipositor, lessening the interval separating them from other primitive Orthoptera. Nevertheless they have already acquired many of those peculiarities which distinguish them from all other insects, notably the rounded shield-shaped pronotum, the small, flat, retractile head, the characteristic strongly delimited anal area of the front wing, the flat bodies, and, without doubt, the peculiar scurrying motion. The indications are that their habitat was much the same. Their constant association with fossil plants, especially ferns, suggests that they were then, as now, fond of moist low places, with abundant vegetation, along the banks of rivers and marshes. Such differences as are found are those resulting naturally from development and specialization, as increased differentiation between the front and hind wing, greater complexity of the wing venation, and the reduction of the ovipositor by specialization. The indications are that the line representing the cockroaches diverges from that of other insects during the early Carboniferous or pos-

sibly before, and is from that time on a distinct and continuous line. The customary separation of the group into an older and a newer part,—the Paleoblattidæ and the Blattidæ, while in a sense artificial, is nevertheless convenient as marking two fairly distinct stages in the development of the phylum. The two families are best included within a single super-family characterized as follows, and for which the term Blattacea is here suggested:

Running Orthoptera; body flat and carried close to the ground; tergum of the first thoracic segment (pronotum) large, broad, typically shield-shaped; head small, flat, inflexed, capable of being more or less completely withdrawn beneath the pronotum; wings differentiated into a more or less thick front wing, and a thinner, broader hind wing; anal area of the front wing marked off by a strong furrow; hind wing not folded in the earlier forms, folded in the later; ovipositor projecting from the abdomen in the Paleoblattidæ, not, or but slightly, projecting in the Blattidæ.

The geological range of the Blattacea is from the Carboniferous to the present. Of the two families included, the Paleoblattidæ extend from middle or early Carboniferous to the close of the paleozoic, possibly lasting over into early mesozoic; the Blattidæ from late paleozoic or early mesozoic, to the present.

Paleoblattidæ.

Paleoblattariæ Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 26, 1879.
Paleoblattidæ Brongniart, Histoire des Insectes Fossiles, p. 416, 1894.

The Paleoblattidæ, the older and more primitive of the Blattacea, are characterized as follows:

Cockroaches with a well-developed and protruding ovipositor. Eggs probably deposited singly in the ground, in stems, or underneath the bark of trees. Hind wings not folded and consequently lacking differentiation into a brownish resistant, and a thin folded part. Anal area never plicated. Differentiation in texture and venation between the front and hind wings less marked than in the Blattidæ, the front wings being, as a rule, less coriaceous and the main veins in both wings more nearly equally developed. Cross veins, except for the reticulation of the membrane, are not common in the front wings, and are unknown in the hind ones.

Description of Genera and Species, including Nymphs.

Mylacridæ.

The Paleoblattidæ are again subdivided into two subordinate groups, the Mylacridæ* and the Blattinariæ. The former

* The term Mylacridæ in use for this group is misleading, since the termination is that accepted for family names. A better term is Mylacrinariæ to correspond with the coördinate division Blattinariæ.

present the more primitive structure and are not known later than the Coal Measures.

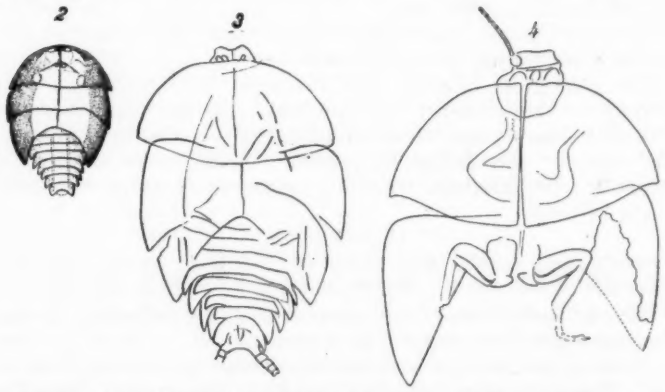
Mylacris.

Scudder, Geol. Surv. Illinois, vol. iii, p. 568, 1868; Mem. Boston Soc. Nat. Hist., vol. iii, pt. 1, p. 40, 1879.

Mylacris diplodiscus. Text-figures 2–4; Plate I, Figure 3.

Dipeltis diplodiscus Packard, Amer. Nat., vol. xix, p. 293, 1885; Mem. Nat. Acad. Sci., vol. iii, p. 145, 1886, pl. v, figs. 2 and 2ª. Schuchert, Proc. U. S. Nat. Mus., vol. xix, p. 672, 1897, pl. lviii, figs. 2–5. Bernard, Natural Science, vol. xi, p. 397, December, 1897. Gahan, ibid., vol. xii, p. 42, January, 1898; Schuchert, ibid., p. 215, March, 1898. Scudder, in Zittel's Text-Book of Paleontology, Eastman's Translation, p. 687, 1900. Melander, Journal of Geology, vol. xi, p. 185, Feb.–March, 1903, pl. v, fig. 6; pl. vii, fig. 6.

Mylacris diplodiscus Sellards, this Journal, vol. xv, p. 309, April, 1903, pl. vii, fig. 8.



FIGURES 2–4.—*Mylacris* (*Dipeltis*) *diplodiscus;* all figures twice natural size. Figure 2, after Schuchert. Originals of Figures 2 and 4 in the National Museum; original of Figure 3 in the Yale University Museum.

This species is of much interest historically, having been the first nymph cockroach described from this country, although not recognized as such at the time.* No less than seven specimens of this species in different stages of development have now been obtained. The smallest individual observed, from the National Museum collection, figured by Schuchert (*loc. cit.*), and copied here (Figure 2), is hardly more than one centimeter in length. The pronotum is rounded in front and pointed at the lateral angles. The wing pads appear as lateral extensions of the thoracic terga, the two pairs being very similar in size, shape, and texture. The abdomen is small, short, and narrows

* For a history of *Dipeltis* and a redescription of the type specimen, the reader may consult the short paper by the writer referred to above.

rapidly from about the seventh to the tenth segment. The thorax is unusually large in proportion to the abdomen, being approximately twice as broad and twice as long as the abdomen. A later stage is represented by a specimen 14^{mm} long, and presents much the same proportions. The wing pads have become larger and the front pair now somewhat overlap the second pair. The specimen shown in Figure 3 has reached a length of 2^{cm}, exclusive of the head and cerci. The head as seen on this and other specimens is large; the eyes are here preserved as elongate ovate impressions. The largest specimens, which are presumably approaching maturity, are 3^{cm} in length. The pronotum in these later stages becomes slightly rounded at the lateral angles, the front wings are noticeably larger than the hind, and traces of the venation have appeared. The adult, when identified, will probably be found to have a broad pronotum rounded at the lateral corners, with wings longer than the short abdomen, and resembling in a general way the adults of *M. elongata*, which has, however, a proportionally longer thorax and a more strongly arched boxlike body. The most striking character of the species in its larval stages is the short abdomen and the large, broad thorax. The antennæ, cerci, sterna, and parts of the legs have been observed. The nymphs, not having been identified with the adults, may conveniently retain for the present the specific name already assigned to them. The reference of the species to the genus *Mylacris* is provisional, *Mylacris* being used, as explained above, in a general sense for nymphs of the *Mylacridæ*.*

Formation and Locality.—All the known specimens of this species are from the Coal Measures at Mazon Creek, Illinois.

Mylacris elongata. Text-figures 6–9; and Plate I, Figure 1.

Scudder, Bull. No. 124, U. S. Geol. Surv., p. 41, pl. i, fig. 6, 1895.

The thorax of the nymph referred to this species is large, the larger front wings overlapping the hind ones. The mould of the dorsal surface, from which Figure 6 is made, shows the ten segments of the abdomen. The first to the third terga are reduced. The abdomen is broadest at the fifth segment, and narrows to the tenth. The ninth and tenth terga of this species appear to be closely united, the last being small. A thickened line extends from the ninth across the tenth. The

* Mr. A. L. Melander, in a foot-note accompanying his reference cited in the synonymy above, suggests that the pronotum of this form agrees very well with that of *Promylacris rigida*. From a direct comparison of the types of the two species it seems probable that the pronotum of *Promylacris rigida*, which in the type specimen is distorted, and from which, moreover, the matrix has never been entirely removed, is proportionally less broad than that of *M. diplodiscus*.

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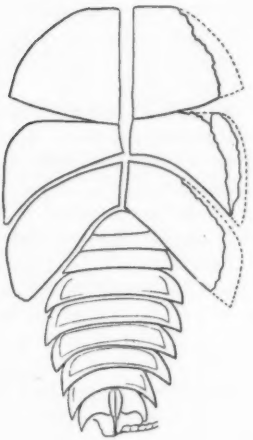

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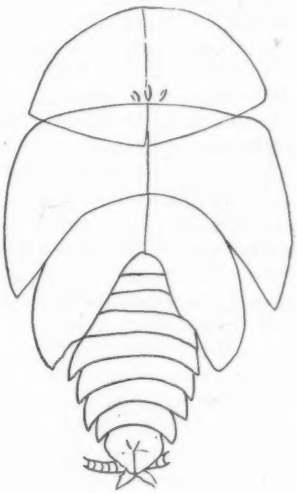

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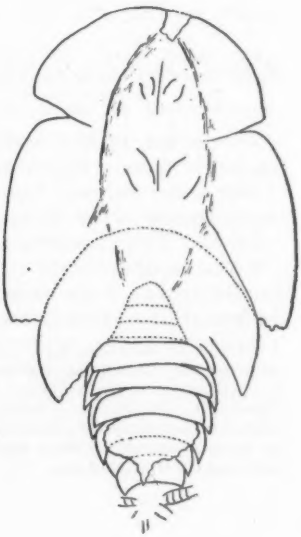


FIGURE 5.—*Mylacris anceps* sp. nov. Cast-off integument of nymph.

FIGURE 6.—Nymph of *Mylacris elongata* Scudder. The illustration is taken from the cast of the dorsal surface. The cerci of this species, as of *M. anceps*, stand at right angles to the axis of the body. The indistinct organ at the end of the abdomen may possibly be the crushed ovipositor.

FIGURE 7.—Same specimen; looking down upon dorsal surface. From this view a depression indicates the outline of the body. The notch in the front of the pronotum is due to erosion, the specimen having been exposed to weathering agents from 1871 to 1880 (see text, p. 119). The whole dorsal surface has suffered erosion during these nine years. Over the abdomen the terga have thus been partly removed, exposing the sterna.

FIGURE 8.—Adult *M. elongata*. The much crushed head is partly exposed. The pronotum, by the time the adult condition is reached, has become, as usual, much rounded at the corners. The dorsal surface has been partly removed to expose the legs and the abdominal sterna.

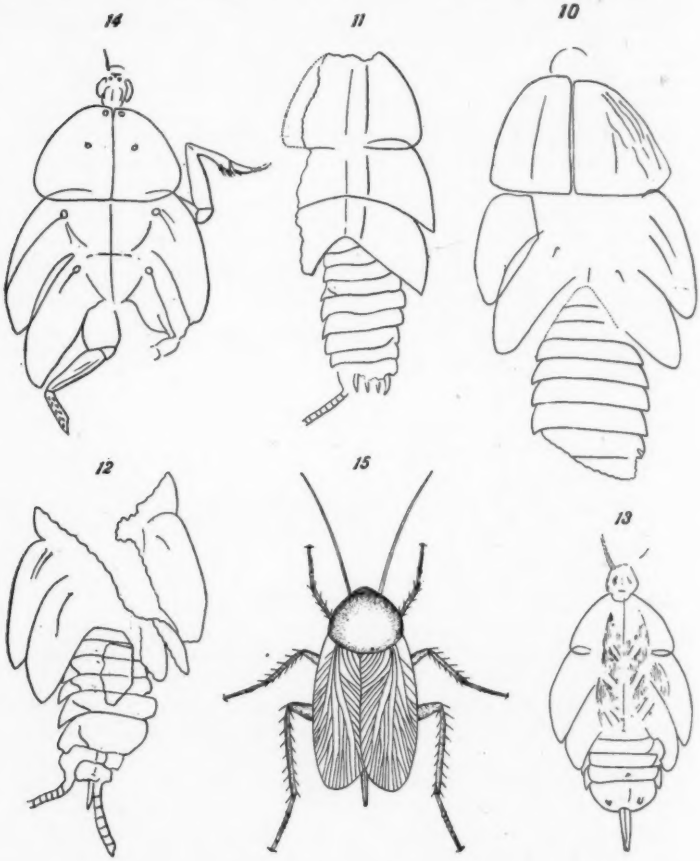
FIGURE 9.—Head of same specimen.

Figures 5–8 enlarged approximately two diameters; Figure 9, x4. All were obtained from the Coal Measures of Mazon Creek, Illinois. Originals in the Yale University Museum.

cerci are directed at right angles to the axis of the body and are comparatively strong, the joints near the base being twice as broad as long. The body of the insect (Figure 7) has suffered considerable erosion, as a result of which the terga of the abdomen have been removed, except at the edges, thus exposing the sterna. The more rapid erosion of the integument of the thorax over the head and legs reveals the location of these organs.* The sterna as seen in the illustration are of the normal Mylacrid type. The seventh is enlarged and rounded. A portion of some organ, probably the ovipositor, is seen on the inner side of the seventh sternum. At the end of the abdomen of both fossil and mould may be seen what appears to be the two parts of the ovipositor separated and spread open by crushing.

Two adults are referred to this species. The body of the adult exclusive of the head is 36^{mm} long. The abdomen is short as compared with the long thorax. The wings are large, the two pairs being of equal length and much longer than the abdomen. The body is arched transversely. The tegmina have a prominent humeral angle and fit down boxlike over the sides of the body. The pronotum is broad and rounded at the angles and has a full posterior border. The sterna of the specimen figured are visible. As in the nymph, the seventh sternum is enlarged and rounded, and has a depressed line which may represent the impression of the thickened ridge on the ninth tergum. The identification of the two adults with

* The history of the two parts of this specimen is of interest. The mould (Figure 6) was collected by Mr. S. S. Strong and sent to the Yale Museum in 1871 (lot No. 199). The opposite side of the nodule, evidently lost at the time, remained exposed until rediscovered by Mr. Strong and sent to the Yale collection in 1880 (lot No. 1400), having eroded during the intervening nine years to the extent mentioned in the text.



Etoblattina mazona Scudder.

FIGURE 10.—A nymph approaching maturity. The specimen has suffered lateral crushing, causing a wrinkling of the pronotum and giving the abdomen probably an unnatural width.

FIGURE 11.—A small nymph in which the parts of the ovipositor have not yet united. Two pairs are seen, the outer being larger and more curved, the inner smaller and straighter. Some other organs, probably a third pair of ovipositors, are indistinctly seen.

FIGURE 12.—A later stage in which the parts have become united and the ovipositor projects from the abdomen. The enlarged seventh sternum is here seen to lie underneath the eighth, ninth, and tenth terga.

FIGURE 13.—A nymph which, having the terga removed, exposes more of the ovipositor and sterna. The view obtained here as a result of the removal of the terga is of the upper (inner) side of the sterna. The ovipositor is seen to pass on the inner (upper) side of the seventh sternum. The impression of the dorsal surface of this specimen shows the ten terga and the cerci in position, confirming the relative position of the seventh sternum and the eighth, ninth, and tenth terga described for the specimen above (Figure 12).

FIGURE 14.—A nymph approaching maturity.

FIGURE 15.—Restoration of *Etoblattina mazona* Scudder, based upon the type specimen, the wings and pronotum of which are well preserved, and also upon the several nymphs now known preserving practically all parts of the body.

Figures 10–12, x3; Figure 15. natural size; all others, x2. All are from the Coal Measures of Mazon Creek, Illinois. Original of Figure 14 in the National Museum; all others in the Yale University Museum.

Scudder's species *Mylacris elongata* is based on the close agreement in the shape and venation of the tegmina. The connection between nymph and adult is inferred from the relative proportion in size between the thorax and abdomen, the large wings already evident in the nymph, and the similar boxlike shape of the body.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois.

Mylacris anceps sp. nov. Text-figure 5.

The specific name *M. anceps* is proposed for the nymph illustrated in Figure 5, which can not at present be referred to its proper adult species. The most marked characters of the species are its long abdomen and short wings as compared with the species just described. The wings are unusually short considering the size of the nymph. The abdomen is almost or quite as long as the thorax, narrowly elliptical in outline, broadest at the fourth or fifth segment, sloping gradually to the tenth. The tenth tergum is small, and, as in the last species, apparently consolidated with the ninth, the union being strengthened by a strong ridge running down the center. The cerci in this species are also directed at right angles to the axis of the body. The adults will probably be found to have a proportionately broad and long abdomen.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois. Type specimen in the Yale University Museum.

BLATTINARIÆ.

Etoblattina.

Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 56, 1879.

Etoblattina mazona. Text-figures 10–16; and Plate I, Figure 2.

Scudder, Proc. Boston Soc. Nat. Hist., vol. xxi, p. 391, 1882.

Etoblattina mazona is at present the most completely known paleozoic cockroach. A rather full description will therefore be given of several individuals representing stages in the development of the species. A restoration of the species as now known is also attempted. The smallest specimen seen is 15^{mm} long. The body is slender and the two wings appear as

triangular, pointed extensions of the meso- and meta-thoracic terga, equal in size and of a similar texture. The pronotum at this stage is abruptly truncated at its posterior margin. The abdomen is slender and long. The sterna of the specimen are partly exposed. The most remarkable feature in the fossil, giving it an especial interest, is the presence near the end of the abdomen of two pairs of organs and traces of a third, which appear to represent the parts of the ovipositor not yet united (Figure 11). These lie at a level below the edges of the terga and the cerci, but above that of the sterna. The stage of development of the ovipositor represented by this specimen is very similar to that of the young *Locusta* illustrated by Dewitz (*loc. cit.*). A later stage in the ontogeny of the species is represented by Figure 13. The wings are now directed obliquely backward, and are more arched. The dorsal integument of the abdomen is here entirely removed from the seventh sternum and ovipositor and from the rest of the abdomen except at the edges. The parts of the ovipositor have now become united, the line of union being indicated by a furrow. The ovipositor is seen to pass on the inner side of the large seventh sternum, and is incomplete, being broken at the tip. The part preserved is 3^{mm} long. The opposite side of the nodule shows the ten segments of the abdomen complete, together with the cerci. The sterna of the slightly larger individual shown in Figure 12 are also partly exposed. On the inner side of the seventh is what appears to be the ovipositor lying at a lower level and passing beneath the tenth tergum. The abdomen has suffered lateral crushing in fossilization so that the sterna are displaced to the right and the ovipositor lies almost under the right cercus. Figure 14 represents one of the larger specimens of this species. Besides the thorax and wings, the head and two legs are preserved. On the head can be seen the outline of the two rather large eyes. Toward the front of the head are two small paired bumps and between these a smaller elevation. A line at the top of the head divides the epicranial plates. The pronotum at this stage has rounded angles, a full posterior border, and overlaps the base of the front wings. A pair of elevations is seen close to the median line and near the front of the pronotum. A second pair is placed farther back and out from the median line. The pits observed by Schuchert on *Mylacris (Dipeltis) diplodiscus* are doubtless of the same nature. The front and hind wings are as yet scarcely differentiated from each other either in size or texture. They are still united to the terga by their entire base, although a thickened spot, represented in the drawing, indicates the place at which the articulation of the wing is forming. A delicate

median line divides the thorax, which may denote the line of rupture of the integument in moulting and also that the part preserved is here, as in most instances, the cast-off integument. This line is, however, not more marked than that on the thorax of some living nymphs, resulting from the union of the lateral halves of the terga, and the line along which the break ultimately occurs at the time of moulting. The femur, tibia, and tarsus of the first leg on the right side are preserved. The femur is smooth and of about the same length as the tibia. The tibia, on the contrary, is strongly spinous. The first joint of the tarsus is comparatively long; the others are short. The number of joints in the tarsus can not be made out. The left leg of the third pair shows most of the coxa, the trochanter, the femur, and part of the tibia. The femur is stouter than that of the first pair of legs and is likewise smooth. The tibia is slender and preserves the bases of the spines. The trochanter of this leg, also, is seen as a triangular piece uniting the femur and coxa. As in other cockroaches, a progressive rounding during growth of the posterior border of the pronotum is evident, which gives the pronotum of the adult a circular form. The thin texture and the ornamentation of the pronotum are characteristic and serve to confirm the connection of the nymphs and adults.

The restoration given here (Figure 15), is based on the several nymphs of the species and the adult which served as the type specimen, the pronotum of which, more completely uncovered, is here refigured (Figure 16). The cockroach is represented in the resting position. Spines have not been observed on the femur. That the tibia is spinous is shown, however, in Figure 14. The ovipositor of *E. mazona* was apparently of medium length. At the time the restoration given by Professor Scudder was made (Mem. Boston Soc., vol. iii, pl. x, 1882), the presence of the ovipositor and the spinous character of the tibia were unknown.

16

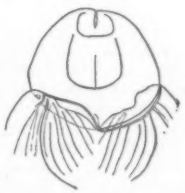


FIGURE 16. — Pronotum of adult of *E. mazona*. × 2.

Formation and Locality.—Coal Measures, Mazon Creek, Illinois.

Etoblattina juvenis sp. nov. Text-figures 17–21.

The most common nymph at the Lawrence locality is a species with large broad abdomen, the terga having well-developed free edges, and the sterna, rounded corners. Two instructive individuals of this species, lying on a small slab, are shown in their relative positions in Figure 17. The dorsal integument of the nymph at the right of the figure has split down the

center and been pushed to each side, thus exposing the basal elements of the legs. The most striking feature is the large size of the second segment,—the trochanter, which, instead of being wedged into the lower angle between the femur and coxa, is apparently joined squarely to the femur. The specimen has been crushed and drawn out laterally, thus causing the trochanters on the left to appear abnormally large and those on the right too small. The median organ in front of the first pair of legs, probably one of the sternal elements, has suffered a similar distortion. The basal part of the ovipositor, 9mm long, is preserved in place. Parts of the body are scattered about

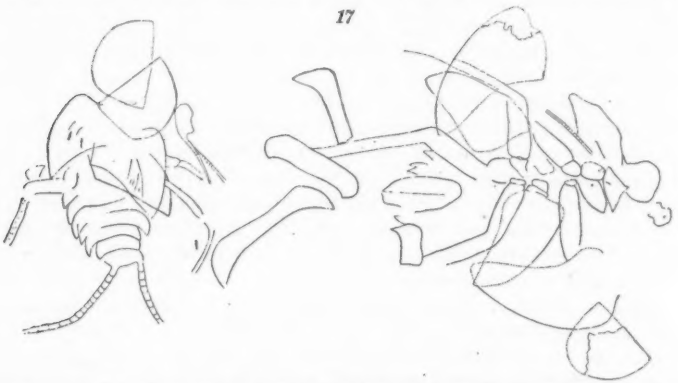


FIGURE 17.—*Etoblattina juvenis* sp. nov.; natural size. Two specimens lying near each other on the same slab. The nymph on the left shows a considerable part of the cerci, which in this species are very long. Both have the legs more or less completely preserved. As a result of crushing, the integument of the nymph at the right has split along the dorsal line, and, spreading laterally, exposed the basal elements of the legs otherwise rarely seen. The species has a large, prominent ovipositor, which is preserved on the specimen at the right; it is badly crushed, however, and its shape poorly defined. Some terga with pointed angles, and sterna with rounded angles, are seen detached and lying between the two nymphs.

Original from the Upper Coal Measures at Lawrence, Kansas, in the writer's collection.

on the slab. Detached terga with their pointed edges, and one of the sterna with rounded edges, are seen lying between the two nymphs. The nymph on the left of the figure is more nearly entire. The head is displaced to the right of the pronotum. The antennæ are very well preserved, but the other structures of the head are too much crushed to be recognized. On the pronotum is seen a circular mark characteristic of the species. Traces of the venation are evident, the cubitus and its branches, as is usual among nymphs, being the most distinct. Parts of the legs are exposed at the sides of the body. The tibia is spinous and the tarsus apparently long. The pointed

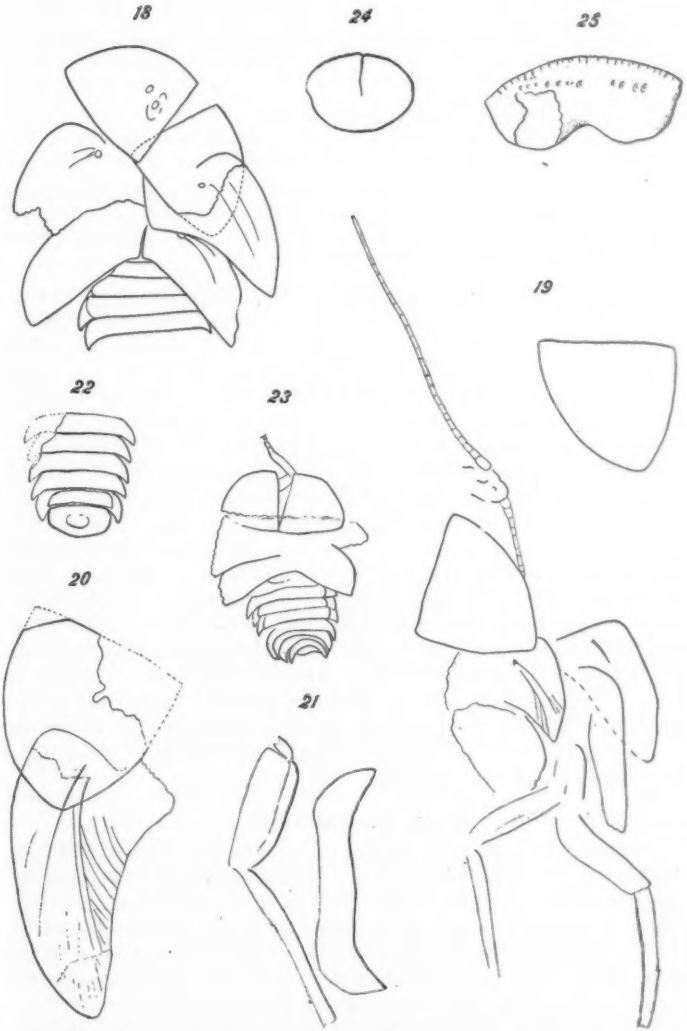


FIGURE 18.—*Etoblattina juvenis* sp. nov. A nymph, of which the thorax and a part of the abdomen are preserved. The abdominal sterna are seen in outline through the terga.

FIGURE 19.—*E. juvenis* sp. nov. A nymph of which a considerable part of the long antennæ and the outline of the head are preserved. The two parts of the pronotum are separated. The absence of spines on the tibia is probably due to imperfect preservation.

FIGURE 20.—*E. juvenis* sp. nov. One wing and half of pronotum of nearly mature nymph.

FIGURE 21.—Trochanter, femur, and one abdominal tergum of nymph.

FIGURE 22.—*Spiloblattina.* Part of abdomen in which are seen indications of color areas resembling those of *Spiloblattina*, to which genus the specimen is provisionally referred.

FIGURE 23.—A small nymph, genus undetermined.

FIGURE 24.—Pronotum of small, probably adult, cockroach.

FIGURE 25.—An undetermined fossil, resembling very much the egg case of cockroaches.

All figures are twice natural size. Original of Figures 18 and 19 in the University of Kansas collection; all others in the writer's collection. All are from the Upper Coal Measures. Figure 23 is from Deer Creek, twelve miles S.W. of Lawrence; others are from Lawrence, Kansas.

free edges of the terga are evident. The cerci, although incomplete, are unusually long. The specimen figured and its counterpart are in the writer's collection. A number of other nymphs of this species have been obtained from the same locality, one of which (University of Kansas collection) is illustrated in Figure 18. The pointed terga and rounded sterna, similar to the detached terga and sternum of Figure 17, are here seen in place. The large nymph, previously figured, is probably also of this species, although the body is larger and more bulky.* The free edges of the terga from the third to the ninth are very prominent. The tenth sternum is rounded. The sterna with their rounded corners are seen in outline through the terga. A part of the strong femur is seen on the right, and a few segments of the antennæ are visible beyond it. The reference of these nymphs to the genus *Etoblattina* is supported by the rounded character of the sterna, which are similar to those of *E. mazona*, and by association, more than half of the adult species from the Lawrence locality belonging to this genus.

Formation and Locality.—Lawrence Shales, Upper Coal Measures, Lawrence, Kansas.

Genus Undetermined.

The generic reference of the small nymph (Figure 23) is in doubt. The abdomen has been torn and crushed, but the ten segments can be made out. A few of the sterna seen in outline through the terga are pointed at their posterior corners. A tibia, tarsus, and a part of the femur lie in front of the pronotum. The number of segments of the tarsus can not be made out, but the claw terminating the foot is preserved.

The pronotum (Figure 24) is found detached, and judging from its rounded form probably belongs to an adult.

Formation and Locality.—Both the nymph of Figure 23 and the pronotum of Figure 24 came from the Lawrence Shales, Upper Coal Measures, Lawrence, Kansas.

* This Journal, vol. xv, April, 1903, pl. vii, fig. 5.

[To be continued.]

Art. XVII.—*A Remarkable Parasite from the Devonian Rocks of the Hudson Bay Slope;* by W. A. Parks.

It was the writer's privilege, during the summer of 1903, to be engaged on certain geological investigations in the basin of the Moose river, and the opportunity was afforded to do a small amount of collecting from the Devonian area surrounding the southern end of James Bay. This examination was conducted, more particularly, on the Kwataboahegan river, a stream entering the Moose about 12 miles above Moose Factory, which is situated near the mouth of the great river. An account of the fauna of the Lower Devonian rocks there exposed will appear in the Report of the Bureau of Mines of Ontario for the year 1904. In addition to some new species, described in the article referred to, the attention of the writer was drawn to what appeared to be a new species of Platyostoma with a remarkable surface ornamentation. This fossil, which occurs abundantly, has the shape and general appearance of *Platyostoma lineata*, but the surface differs from that species by the possession of a peculiar reticulated ornamentation.

In nearly all cases, casts only of the numerous gasteropods characteristic of the series are found; only one Platyostoma was collected retaining any trace of the shell which shows the ordinary fine lines presented by *P. lineata*. Among the great number of external casts of this species many were seen to present a constant reticulated appearance, as if the outer ornamented part of the shell had been preserved after the inner layer had been dissolved. Such was the conclusion arrived at in the field; but microscopic examination in the laboratory renders this conclusion very improbable. Many of these external casts show the impression of the lines of growth characteristic of the exterior of *P. lineata*, proving that the structure observed is something entirely external to the shell of the gasteropod, and therefore to be regarded as of a parasitic nature. This parasite is most intimately associated with the shell penetrating into the umbilicus and into the deepest parts of the sutures. This fact makes it very difficult to decide that we are not dealing with an external layer as first suggested.

The lower or basal aspect of the parasite is well seen on the casts of the exterior of the Platyostoma. The outer surface was not observed, as the organism is so persistently imbedded in the matrix as to render all attempts to free it abortive.

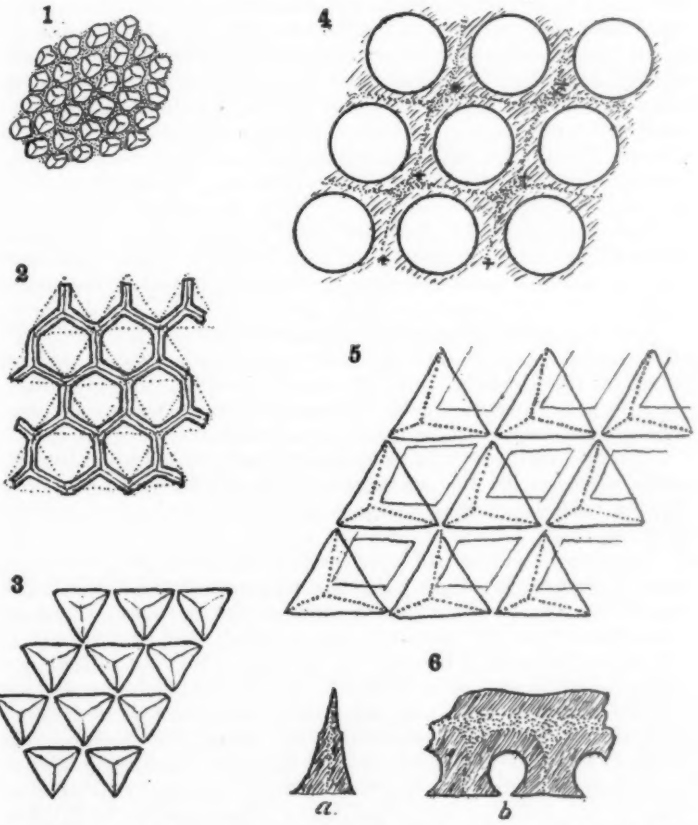
At least two species of this creature occur, differing in the size of the elements composing them and in some minor points

of structure. The finer one is more abundant and better preserved; it is therefore taken as a type of the genus and is described below in some detail.

The cast of the Platyostoma is seen to be covered with round white spots, separated by narrow brownish lines. Three of these spots with the intervals between them occupy the space of one millimeter. They are regularly arranged in lines inclined at a slight angle to the sutures of the host. A line may also be drawn through the centers of the spots inclined at an angle of 60 degrees to the first. On close examination these white spots are found to consist of three elements, separated by minute clear lines. These lines are seen to be uniform in arrangement, being approximately parallel in all the spots; see figure 1. Sections a little higher in the organism show that the pillars decrease in size with a corresponding increase in the intervening matter; they also approach a roughly triangular appearance. Still higher, the contiguous angles of adjacent pillars reach out and unite with each other so as to produce an hexagonal ring with the clear lines of the original pillars forming a continuous line around the middle of the ring. The open center of the ring is occupied by the matrix. It is apparent that each alternate angle of the hexagon represents the position of a pillar, while the other angles are situated at the points of coalescence of adjacent pillars. Higher sections show that this reticulation is continued to the surface of the specimen where the white matter forming the borders of the rings unites and covers the central clear portion. The structure of the reticular network is shown in fig. 2. Tangential sections very near the surface of the reticulation show minute points projecting into the openings of the mesh suggesting the septa of a favositoid coral or certain of the hydrocorallines. A second variety is seen to be represented by an almost similar structure except for the fact that the pillars on ascending become markedly triangular in outline and extremely regular in arrangement. The cross section of this variety at the level where the pillars approach each other is seen in figure 3. The structure of the network is the same as in the first variety. It is quite possible that these two are identical, and that better preservation in the one case has resulted in the retention of the sharp triangular outline of the pillars. It is thought better to include them both in one species.

There is, however, another species, characterized by a much larger mesh in the network and by the fact that the meshes are rhomboidal in outline instead of hexagonal. The ascending pillars show the same three fine clear lines separating the element, but, at a certain level, there is a tendency for one of these lines to become shortened, so that, on the coalescence of

the elements of adjacent pillars, two of the sides of the resulting hexagon are much shorter than the others. A little higher in the skeleton these sides practically disappear, giving in consequence rhomboidal openings in the reticulation. A tangential section of this form is seen in fig. 4, while in fig. 5 is seen a diagrammatic representation of the manner in which the rhom-



boidal meshes originate. In this diagram the center of the pillar is represented by a small cross which will be seen not to conform to the nodes of the reticulation.

In either species it will be observed that the want of symmetry in all directions around the pillars will render vertical sections extremely variable and difficult of interpretation. It is further apparent that vertical sections will cut the reticulated

portion at different points, so that in any one section greatly different appearances will be presented by this part of the skeleton. Vertical sections, however, show that the pillars contract in diameter and the elements composing them gradually arch over and unite, so that certain parts of the network are supported on elliptical arches open at the bottom to the fine brown lines separating the pillars at the base. The interpretation is easy, therefore, that each alternate angle of the hexagonal mesh is supported on a pillar and the alternate angles on a vaulted arch derived from the fused elements of those pillars. Nothing further is revealed by vertical sections, variable as they are, except that the clear matter forming the dividing lines in the pillars expands in the reticulation and ascends almost to the surface of the network, where it is covered by the white matter forming the sides of the meshes. Vertical sections are shown in fig. 6.

The thickness of the entire encrustation in the hexagonal variety is about three-fourths of a millimeter. The rhomboidal species attains a greater height, possibly as much as two millimeters.

The zoological affinities of these parasites is somewhat difficult to determine. The regularly reticulated skeleton at first suggests the Bryozoa, but the peculiar support on the pillars and the structure of the skeletal matter are features that must remove the organism from that association.

The occurrence of the parasite on shells of gastropods naturally leads one to the consideration of Hydractinia, and it is highly probable that our species are closely related to that organism.

Tangential sections of Hydractinia show a network of chitinous fibers with round pillar-like elements at the nodes. The nearer to the base that such sections are prepared the more pronounced are the regularity of the mesh and the individuality of the pillars. Higher sections show that the reticulation becomes more and more irregular as we approach the surface. In the short time spent in examining the skeleton of Hydractinia the writer was unable to cut tangential sections low enough to cross the pillars below the first connecting bars, so that a similarity of mode of attachment can not at present be urged in support of the relationship of our species to Hydractinia.

The two organisms, however, agree in the possession of distinct ascending pillars which give rise to a pronounced reticulation by the coalescence of horizontal elements derived from those pillars. A distinct difference is seen in the fact that our species produce but one layer of meshes which has a considerable vertical extent, whereas Hydractinia repeats this process

and in a more and more irregular manner as it increases in age. Further, the meshes of the network in Hydractinia are practically without any tendency to form tubes, i.e. have no vertical extent. No evidence of polymorphism is to be observed in the species under review. Another point of similarity is seen in the fact that the base of a Hydractinia colony shows a more resistant brownish layer where it is attached to the host; the brown matter lying between the bases of the pillars in our species may well be analogous to this structure in Hydractinia.* The presence of the minute septa-like projections near the surface of the network suggests that the openings of the meshes were occupied by individual hydroids with very short vertical extent. Such an interpretation would place the creature near to Professor Duncan's Stoliczkaria. This relationship can, of course, be maintained only on the supposition that the coenenchyma of Stoliczkaria is entirely unrepresented in our species.†

There is little doubt, therefore, that the new genus may be safely placed under the Hydroida with a considerable resemblance to Hydractinia and a suggestion of the structure of Stoliczkaria. If this relationship is accepted, the study of the present species throws considerable light on the manner in which the horizontal elements arise from the ascending pillars in all this class of creatures. Further, we have but to assume the closing in of the meshes and the repetition of the process of growth to arrive at the origin of the skeleton of that large and diverse group, the Stromatoporoidea.

The preferential parasitism exhibited by this organism at so low a stage as the base of the Devonian is a matter of interest. Further, if we accept its hydroid affinities, and omit the graptolites and stromatoporoids, we have in this creature the earliest of the Hydroida, excepting, of course, the very doubtful Corynoides and Palæocoryne.‡

Tristylotus gen. nov.

Encrusting parasite on species of Platyostoma. Skeleton probably chitinous or partially calcified, consisting of a continuous polygonal reticulation, supported on short pillars. These pillars are composed of three elements, are sub-circular at the point of attachment and triangular above. The reticulation arises by the drawing out of the angles of the triangular pillars and the coalescence of the points thus produced.

Tristylotus—*στυλωτός*, supported on pillars.

* Nicholson & Lydekker—Manual of Palæontology, Vol. I, p. 198.

† Ibid., p. 228.

‡ Ray Society for 1870. Monograph of the Tubularian Hydroids, George James Allman, M.D., p. 170 et seq.

Tristylotus hexagonus sp. nov.

The meshes of the network are hexagonal and small.

Tristylotus rhomboideus.

The meshes of the network are rhomboidal and larger.

The writer is indebted to Professor Ramsay Wright of the University of Toronto for suggestions regarding the affinity of Tristylotus and for the coining of the generic name.

DESCRIPTION OF FIGURES (p. 137).

Tristylotus hexagonus

Fig. 1.—Base of the parasite as it appears on the external cast of Platyostoma. Enlarged 30 times.

Fig. 2.—Diagram to show the origin of the hexagonal network from the triangular pillars. The orginal position and the outline of the pillars are shown in dotted lines. The fine lines show the clear central portion of the mesh. Enlarged about 75 times.

Fig. 3.—Cross section of the pillars in one variety at a level just below where they begin to unite. Enlarged 75 times.

Fig. 6.—(a) Vertical section through a pillar in a direction across the web of the network. (b) Vertical section through two pillars in a direction following the web of the network. Dotted part is the clear central portion. Striated part represents the white matter. Enlarged 30 times.

Tristylotus rhomboideus

Fig. 4.—Tangential section through the reticulated portion. The positions of the centers of the pillars are indicated by small crosses. The dotted portion represents the clear tissue and the striated portion the white matter. The openings in the meshes are shown round in the diagram ; this is not strictly correct, as they conform more or less to the shape of the mesh. Enlarged about 60 times.

Fig. 5.—Diagram to illustrate the origin of the rhomboidal meshes. The pillars are indicated by heavy lines. The dotted lines represent the clear lines dividing the pillars into three parts. One of these lines is seen to be much reduced in length. It is this shortening that results in the formation of rhomboidal instead of hexagonal meshes. The outlines of the resulting rhomboidal meshes are shown in fine lines.

Art. XVIII.—*Asterolepid Appendages;* by C. R. Eastman.

The renewed interest which has become manifest in the study of the earliest known fish-like vertebrates bids fair to lead to a clearer understanding of the problems presented, if not indeed to their immediate solution. One of the most puzzling riddles is that concerning the derivation and homology of the pectoral limbs, or "swimming appendages" of the *Asterolepidæ*, the only family of Ostracophores in which such organs occur. Different interpretations of their nature have led to a wide range of opinion in regard to the relations of Ostracophores in general, some authors uniting them with fishes proper and others separating them, some deriving them from the Elasmobranch stem, some from the Crossopterygian, and some even from Arachnids. It is still a mooted point whether Ostracophores and Arthrodires are genetically related, some favoring the retention and others the abolition of the group *Placodermata* as originally proposed by M'Coy. It is upon controverted questions of this nature that a study of Asterolepid appendages may be expected to throw some light.

A variety of opinions has been expressed concerning the probable origin and homology of these organs. Thus, there may be noted: first, the theory that they partake of the nature of Arthropod appendages, on the assumption that Ostracophores are descended from Arthropods; secondly, the theory which explains Asterolepid limbs as the produced and jointed head-angles, or "cornua," of forms like *Cephalaspis;* thirdly, the theory that they are derived from a fixed spine attached to the body, similar to the spinous appendage of *Acanthaspis;* fourthly, the theory that they are derived from the lobate Crossopterygian pectoral fin by a process of reduction and specialization; and lastly, the theory that they are independently derived.

The first two of these hypotheses are evidently founded upon complete misconceptions of the structure and position of Asterolepid limbs, and may be summarily dismissed. The third, which explains them as having become evolved from a fixed spine, presupposes anomalous, if not impossible conditions. Neither can they be looked upon as modified pectoral fin-spines, the remainder of the fin having become atrophied; for no similar case of reduction is known amongst fishes. The fourth suggestion, that these members are derived from specialization of Crossopterygian pectoral fins, has recently been put forward by Mr. C. Tate Regan,* and has not yet been discussed. The foremost objection that may be urged against this theory is that it

* Regan, C. T., The Phylogeny of the Teleostomi (Ann. Mag. Nat. Hist. ser. 7, vol. xiii, pp. 329–349), 1904.

rests upon the unproven hypothesis that Asterolepids are highly modified Crossopterygians. Or, to state the converse proposition, the theory that these two groups are genetically related depends upon whether the modified limbs of the one can be homologized with the lobate pectoral fin of the other, there being absolutely no other characters which can be said to indicate community of origin.

The absence of a lower jaw in Ostracophores, the dissimilar arrangement and structure of their head-bones, armouring of the body, single dorsal fin without either dermal rays or basal supports, heterocercal tail, and absence of both pelvic and pectoral girdles, are characters which emphasize the violent contrast between forms like *Pterichthys* and Crossopterygians. That the latter are descended from a heterocercal ancestor is not to be questioned, but if we admit the soundness of Mr. Regan's conclusion that Asterolepids are highly modified Crossopterygians, how are we to explain their reversion to the primitive heterocercal condition, after having passed through the homocercal? The anterior pair of limbs could hardly have become so highly modified, without the hinder pair having also undergone specialization. But even assuming, for sake of argument, that the pelvic fins have become lost, we should expect to find remnants of a girdle, and in any case some indication of a pectoral arch, corresponding to these structures in Crossopterygians; whereas in fact we do not.

The Asterolepid paddle is not made up of articulated rays, but is simply a muscular extension of the body encased in dermal plates. An appendicular skeleton is wanting, and the external covering plates are attached to the body-armour by a complicated joint, one of the dermal plates being pierced for the passage of nerves and nutrient canals; hence it is clear that in structure and mode of attachment these limbs differ radically from normal Teleost conditions. The fact that Ostracophores possess a much greater antiquity than Crossopterygians also militates against the assumption that they are modified descendants of the latter. It is likewise impossible to reconcile the geological occurrence of the groups to which *Cephalaspis* and *Pterichthys* belong with the view expressed by Mr. Regan that the former is a specialized Asterolepid.

There remains finally the theory, which appears to be not very generally accepted, that Asterolepid limbs have been independently derived. The absence of an appendicular skeleton, and the peculiar mode of attachment of these organs, offer such striking contrasts to the fins of fishes as to make it impossible to conceive of a homology existing between them. Moreover, paired appendages are absent, so far as known, in all other Ostracophores. Either they were formerly present, and

have become lost through atrophy, or else they were never developed except amongst Antiarcha; and if the latter be true, it is easy to see that Asterolepid appendages are unrelated to the fins of fishes, since they originated in a different way and are constructed upon a different plan. They may be regarded with much probability as having developed from a muscular flap, or integumentary extension of the body, being of kindred nature with tactile or clasping organs, or with the frontal spines of Chimæroids. The fact that one of the dermal plates is pierced and otherwise modified for their attachment would seem to indicate that *pari passu* with the development of body-armour, the paired muscular extensions also became encased in plates. But sphinx-like though the problem be as to how and when these structures originated, the evidence appears tolerably certain that they have not been derived from the fins of Pisces proper.

A word may be said in regard to the assumed "close relationship of the *Coccosteidæ* and *Asterolepidæ*," these families being representative of groups which are united by Mr. Regan, together with the Osteostraci, in a single order of Teleostomi. We regard as abortive this author's comparison of *Coccosteus* with *Pterichthys*, which leads him to the conclusion that "the arrangement of the bones of the head, and especially that of the dermal plates of the body, can easily be reduced to a common plan"; and it is manifestly untrue that "in the arrangement of the bones of the cranial roof *Coccosteus* is almost a typical Crossopterygian." A remote superficial resemblance there may be, in that certain plates are symmetrically disposed with reference to the median line, but no real homology can be claimed to exist between the cranial elements of *Coccosteus* and those of Crossopterygians and Stegocephalians. It is impossible to insist too strongly that the jaw-parts of Coccosteids are totally distinct from those of fishes proper, although a parallel exists between them and the dental plates of Palæozoic Chimæroids. Both the upper and lower jaw of Arthrodires consist of purely dermal ossifications, and teeth, properly speaking, are absent. As for the serrations which sometimes occur along the cutting margin in one or both jaws, and function as teeth, these are not structurally differentiated from the supporting bony tissue. Moreover, the lower dental plate ("gnathal" of Dean), instead of being articulated to the cranium, is suspended freely in the soft parts, similarly as in Chimæroids. There is no evidence of pectoral fins amongst Arthrodires, and the lateral spine which is attached to the ventral armour evidently has nothing in common with the pectoral limb of Asterolepids.

The axial skeleton of *Coccosteus*, as depicted by Jækel* with

*Jækel, O., Ueber Coccosteus und die Beurtheilung der Placodermen (Sitzungsber. Gesell. Naturforsch. Freunde, p. 111), 1902. —— Ueber die Ruderorgane der Placodermen (*ibid.* pp. 178–181), 1893.

its complement of ossified ribs, has a purely mythical existence. There are no vertebral rings, the axis being entirely cartilaginous, and on either side of this occur the neural and hæmal arches. It is the latter which Jækel has represented as ribs. Neither is there a pelvic girdle, as claimed by this author, his so-called "ileum" being erroneously interpreted as such, and inverted in position. The narrow, rod-like portion, instead of being directed dorsally, and attached to the cartilaginous axis, in reality projected outward from the body-wall, being in fact merely a modified anterior fin-ray. There is a well-preserved specimen in the Paris Museum of Natural History which shows these structures in their natural position, followed by the remaining fin-rays in regular sequence; nor is this the only example which confirms the interpretation here given.

Another notable difference between Arthrodires and Asterolepids consists in the structure of the dermal plates covering the head and anterior part of the trunk. The body-armour of Asterolepids very likely originated from the fusion of scales, but Arthrodires are naked without exception, and it can be demonstrated that their dermal plates arose within the integument from secretions on both sides of the initial layer. The process was continuous throughout life, a succession of tuberculated strata being deposited upon the external surface of the earlier formed laminae, and bony tissue being added underneath, also in regular layers. Altogether, the distinction between Arthrodires and Ostracophores is so trenchant and far-reaching, that the revival of the group "Placodermata" for their union appears to be an unwarranted and decidedly retrograde movement. Finally, we must beg to differ from Mr. Regan in his conclusion that "the *Coccosteidæ* are Teleostomi, that the *Asterolepidæ* are allied to the *Coccosteidæ*, and that the *Cephalaspidæ* have been derived—through the *Trematas pidæ*—from the *Asterolepidæ*," this view being unsubstantiated by either morphological or palæontological evidence, and contrary to all probability. Nor can we view with much favor Jækel's extraordinary hypothesis* that Coccosteans are ancestral to Chimæroids.

Harvard University, Cambridge, Mass.

* Jækel, O., Ueber Ramphodus, etc. (Sitzungsber. Gesell. Naturforsch. Freunde, p. 392), 1903.

ART. XIX.—*Electrotropism of Roots;* by AMON B. PLOWMAN. (Preliminary Communication.)

IN a brief report some two years ago on the relations of plant growth to ionization of soil* it was suggested that the turning of root tips toward the anode is most easily accounted for by attributing this reaction to the effect of the electrons, or electric charges of the ions, rather than to any mere chemical effects of the atoms.

Since the publication of that report an extensive study of electrotropic phenomena has been carried on at the Memorial Research Laboratory of Harvard University. The results seem to indicate that the explanation advanced in the above-mentioned paper is entirely correct, and further, that the conclusion that "negative charges stimulate, and positive charges paralyze, the embryonic protoplasm of plants," is well founded.

Many kinds of seedlings have been grown both in ordinary soil and by the water-culture method in the presence of an electric currrent, under the most widely varied conditions of temperature, current density and culture composition, with results which are altogether uniform in kind. Even the least perceptible current passing by the roots will in time overcome their normal geotropic tendency, and will turn their tips toward the anode. The passage of a comparatively strong current for only a few minutes will produce a marked curvature after two or three hours. Vigorous roots have been deflected 90° from their downward course in half an hour by a moderately strong current. In such a case as this, if the current is kept on, the roots grow horizontally toward the anode, while if the current is turned off they either continue curving until a complete coil is formed, or they may gradually bend downward again, forming a double curve. In any case the region of the initial curvature is dwarfed in its growth and does not become nearly as large in diameter as the parts either above or just below. There is also always a flattening of the root on the concave side of the curve. This flattened region always remains white when the root tips are fixed in Flemming's fluid, while the other parts, like normal roots, are blackened by a prolonged action of osmic acid solutions.

A study of the histology of such electrically curved roots shows that the protoplasm on the side nearest the anode has been coagulated and killed by the action of the current. The cells are completely plasmolyzed, and their walls are exceed-

* This Journal, xiv, p. 131, Aug. 1902.

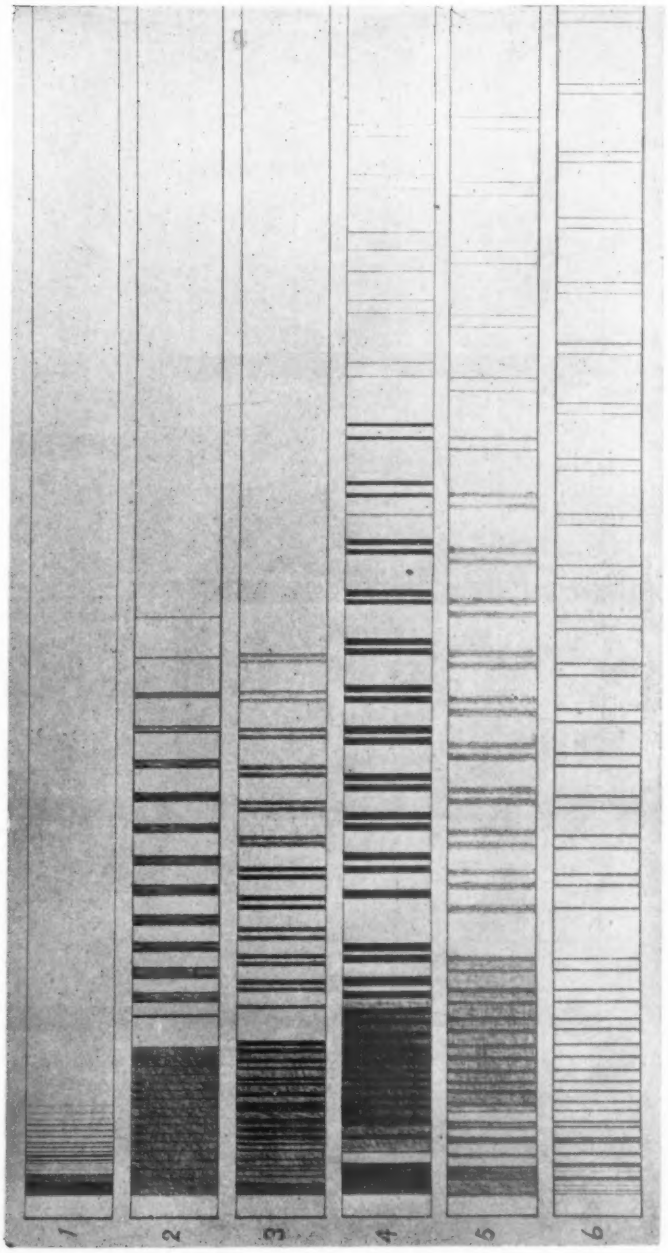
ingly thin and much crushed. Where the root has been acted upon for but a very short time only a few of the cortical cells are affected, while for longer action of the current, or more intense current, the affected zone grows wider and wider, until it may involve the entire structure of the root. In every case the boundary line between the affected zone and the normal part is practically a straight line exactly at right angles to the path of the current. The effect is of course most pronounced in the region of most rapid normal growth. Very weak currents tend to check growth in length, and the roots consequently take on a more stocky appearance. They are often actually thicker than the normal roots of the control.

That the results of these experiments are to be attributed to purely chemical causes is rendered highly improbable by the fact that the results are practically uniform, no matter what the ions of electrolysis may be. Distilled water, very dilute acids, bases, and neutral salts all are apparently alike in this relation, their effects differing only with their varying electrical carrying power. Whatever may be the relation of mass action and of chemical and physical affinity to growth under normal conditions,* it would seem that in the present case the all-important factor is the electron or electric charge of the ion, and, more specifically for our purpose, the positive electron, since it is this one which produces the most striking effects. And so far as is at present known, those effects are always in the same direction, viz: paralysis or actual death of the protoplasm exposed to the action of a positive charge. As for the negative electrons, it seems safe to say that in the majority of cases they are neutral in their relation to living cells, and where any effect is perceptible it is in the way of stimulation of the protoplasm.

There is now in preparation for publication in this Journal a fully illustrated report of this series of experiments, together with a consideration of the practical and theoretical bearings of the facts involved.

Phanerogamic Laboratories, Harvard University, June 1904.

* See the article by J. B. Dandeno, this Journal, xvii, pp. 437–458, June 1904.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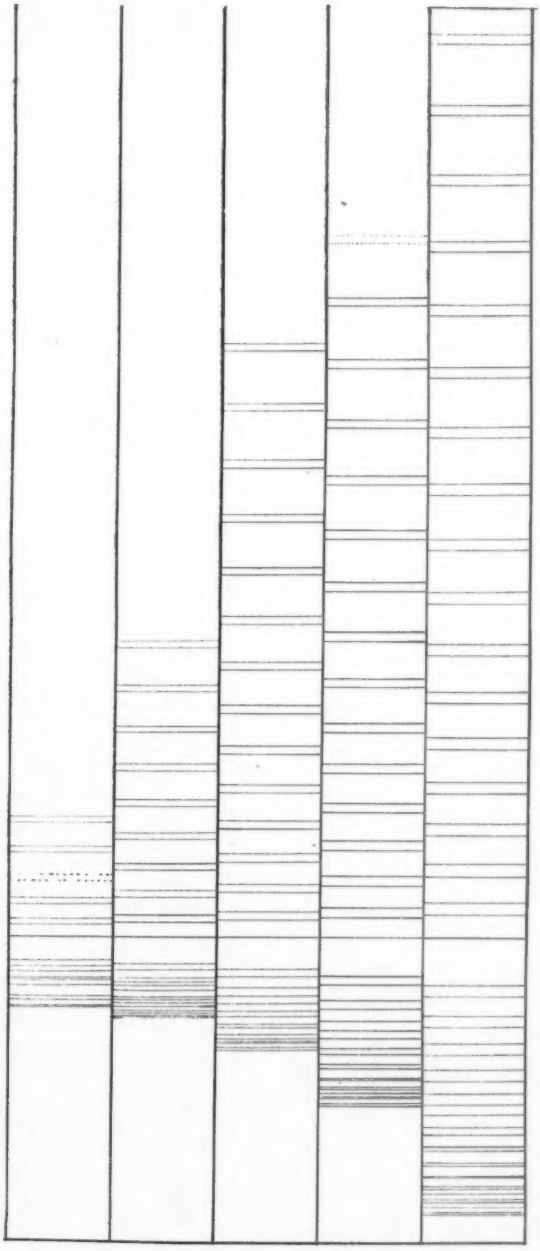
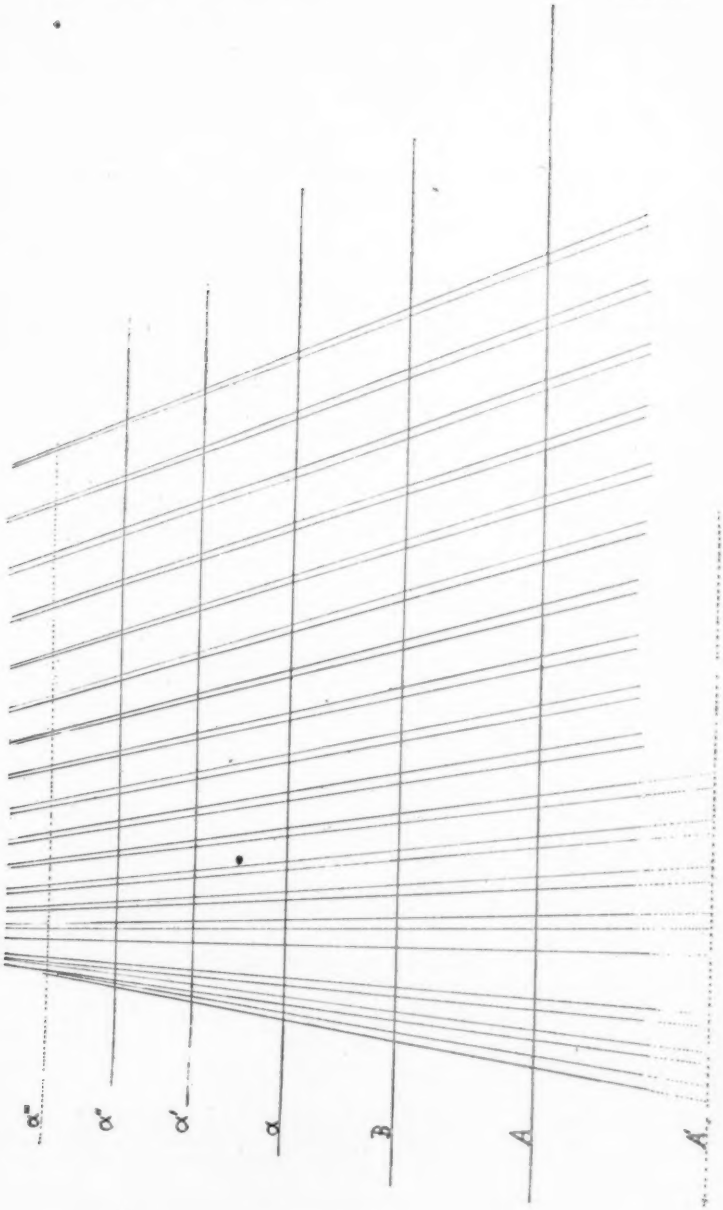



α''
α'
α
B
A
A'

ART. XX.—*On the Oxygen Absorption Bands of the Solar Spectrum;* by O. C. LESTER.* (With Plates II, III and IV.)

THE present research was undertaken with the object of investigating as fully as possible the structure and extent of the oxygen absorption spectrum. This includes a study of the relations existing between the lines of a band and also between the several bands, taking into account those groups above *a* which do not seem to have been considered before. In order to do this satisfactorily it was necessary to have very accurate measurements of the wave lengths. The best determinations previously made are those of Rowland and Higgs, but neither gives all the lines even of the groups A, B, and *a*. Rowland's measurements are nearly complete for B, but he gives only a few for the other two groups. Higgs gives A and B and up to the ninth pair of *a*, and although he and Rowland agree remarkably well in general upon B, judging from the few lines in A which both have measured the agreement is not so good, there being much greater discrepancies than one would expect from the accuracy claimed for their measurements. Hence it seemed worth while to make new determinations of all, or nearly all, the lines previously measured, and in addition many new lines are given. It is hoped, therefore, that the present determination of the wave lengths, taking into account the best previous results, have both extended and unified the measurements on these bands and rendered them, on the whole, more accurate; thus doing for the absorption spectrum of oxygen what a similar work of M. Eisig† has done for the line spectrum.

Because of the precision which it is possible to attain in the measurement of this spectrum, a careful study of the relations subsisting between the lines and bands furnishes an excellent test of the so-called laws of Deslandres for band spectra. They are briefly as follows:

1. In a given band the intervals from one line to the following in any series, calculated in vibration numbers, are in arithmetical progression, i. e., the lines are connected by a relation of the form

$$\frac{1}{\lambda} = N = a + bn^2$$

* Abstract of a thesis presented to the Philosophical Faculty of Yale University, June, 1904, for the degree of Doctor of Philosophy. The paper will appear *in extenso* in the September number of the Astrophysical Journal.

† M. Eisig: Das Linienspektrum des Sauerstoffs, Wied. Ann., li, 1894.

where a and b are constants and n takes on all integral values from 0 to n.

2. When several series arise from the edge of a band they are similar in all respects, and all bands belonging to the same substance have the same number of series.

3. In a series of bands the vibration numbers of the edges form a series similar to that of the lines in a single band.

These laws are the most general in their application that have yet been announced. Deslandres tested them on many spectra, although he never published details showing the exactness of agreement. Kayser and Runge* have obtained a general confirmation upon bands of many substances, including those of N, C, CO, CN, and I, but the laws do not apply equally well to all cases and occasionally appear to degenerate into mere interpolation formulæ. The difficulties in the way of obtaining more exact expressions for the laws are in measuring the wave lengths of bands accurately enough to warrant taking into account small variations of the reciprocals, and, in the case of the third law, in finding a long enough series of bands capable of precise measurement. Most of the bands hitherto investigated are in the upper part of the spectrum, where a small error in the wave length causes a large error in the reciprocal.

Measurement of Wave Lengths.

In the measurements of Rowland and Higgs to which reference is made above, both use the same unit, viz. 10^{-7} mm., and their results appear to be equally accurate. For those lines in B and a which both have measured and for which the agreement is ·01 of a unit or closer, the value adopted in the present work is the mean of the two. In case the disagreement is greater than one would attribute to errors of observation, the value adopted is the mean of my own final result and the one which it confirms, provided such agreement is decidedly stronger with one than with the other. In some cases the mean of all three measurements was taken. For the large majority of the lines in A and a the values given are the means of my own and Higgs' results alone. Those of a' and a'' have not been given before. Since ·01 of a unit is about the limit of accuracy in general, it has been thought best to retain only two decimal places in the wave lengths except in the case of B, where many of the lines are taken as Higgs and Rowland give them. It may be added further that the third decimal place rarely affects even the seventh place of the reciprocal.

* Ueber die Spektren der Elemente: Abhandl. der Berl. Akad., 1888–92.

The measurements of the stronger lines were made as usual with a micrometer microscope. Some of the weak lines had to be strengthened by a fine mark placed on the back of the negative. Others were measured from Rowland's charts, care being taken to set on the center of density of the lines. This last method is better for weak lines, although even here a fine mark must sometimes be used, as any magnification by the micrometer causes some of them to melt into the background.

The group a' was first noted by Jewell.* In the "head" or first band of this group, many of the lines appear double and some foreign lines seem to be present. The line 5789·40, which is the "chief line" of this band corresponding to similar lines in A, B, and a, has been assumed double, as it is in all the other bands. The only indication of being double actually shown is its greater intensity and a certain flatness of the intensity curve characteristic of close doubles. The uniformity of the two series also calls for a close double at this place.

The approximate positions of many of the lines in the group called a'' were calculated from relations established between the other groups, the observed values differing by less than ·2 of a unit from the calculated. The lines are all extremely weak. Some, though not all of them, appear on negatives taken in zero weather, which indicates that they are not water-vapor lines. The first band of the group begins as usual with a double line, possesses a chief line and a final pair in its proper position, as a glance at the groups as shown in Plate III will show. Probably not all the lines present can be seen. Many are so faint as to be visible only on the charts and then only when they are held in particular positions with respect to the light. Some of the lines are stronger on the corresponding chart of Rowland's first series, which is more intense than the second. No attempt has been made to measure many of the lines of this group closer than the nearest half-tenth, which is readily done by estimation. Blunders and mistakes in calculation for all groups except A have been practically eliminated by the use of verniers made to fit Rowland's charts, which, in spite of irregularities in the map scales, enabled any but small mistakes to be detected at once.

* The Absorption Spectrum of Oxygen; Astron. and Astrophys., xii, 1893.

TABLE I.

Note.—Each band contains two series which go by pairs. Consequently to obtain a single series of a band alternate numbers must be taken.

A		B	
First band.	Second band.	First band.	Second band.
7594·00	7621·27	6867·458	6884·080
95·27	23·53	68·457	86·004
94·28	24·77	67·794	86·982
95·55*	27·30	68·780‡	89·183
94·81	28·52	68·337	90·144
96·06	31·28	69·338	92·614
95·55	32·49	69·144	93·559
96·79	35·47	70·130 §	96·282
96·51	36·65	70·220 §	97·197
97·74	39·86	71·180	6900·196
97·70	41·01	71·528	01·116
98·90	44·46	72·489	04·363
99·14	45·59	73·078	05·263
7600·30	49·27	74·039	08·785
00·80	50·40	74·888	09·677
01·95	54·33	75·830	13·449
02·65	55·45	76·953	14·331
03·80	59·62	77·878	18·365
04·73	60·73	79·275	19·245
05·87	65·14	80·173	23·542
07·05	66·25	-----	24·416
08·20	70·89	-----	28·986
09·57	71·97	-----	29·839
10·72	76·86	-----	34·669
12·33	77·92	-----	35·518
13·45	83·06	-----	40·584
15·32	84·11	-----	41·430
16·41	89·47	-----	46·770
----	90·50	-----	47·580?
----	96·11 †	-----	-----
----	97·13 †	-----	-----
----	03·02 †	-----	-----
----	7704·02 †	-----	-----
----	10·16 †	-----	-----
----	11·16 †	-----	-----
----	17·60	-----	-----
----	18·55	-----	

* Higgs gives also 95·42 and 95·66; probably outside edges of this line.

† These lines taken from Higgs' measurements, and from the uniformity of the series preceding they appear a little large.

‡ This line apparently double.

§ These lines constitute the so-called "chief line." Components difficult to measure accurately.

α	
First band.	Second band.
6276·81	6287·94
77·66	89·60
77·03	90·42
77·86	92·35
77·52	93·15
78·29*	95·36
78·29	96·34
79·07	98·64
79·31	99·41
80·08	6302·18
80·61	02·95
81·37	06·00
82·16	06·75
82·93	10·06
84·00	10·81
84·75	14·40
----	15·14
----	19·02
----	19·75†
----	23·92
----	24·64
----	29·10
----	29·82
----	34·55
----	35·26‡
----	40·28
----	40·98
----	46·27
----	46·96

α'	
First band.	Second band.
5788·33	5796·30
(88·55)§	97·76
89·00 (double?)	98·43‖
88·75	5800·18
89·40 (chief line)	00·83
89·40	02·87
(89·71)	03·51
90·07	05·84
90·32 (double?)	06·47
90·97	09·10
91·49	09·72
(91·78)	12·64
92·15	13·25
92·96	16·46¶
93·60	17·07
----	20·58
----	21.16
----	24·94
----	25·52
----	----
----	----
----	----
----	----
----	----
----	----
----	----
----	----

α''	
First band.	Second band.
5377·20	5384·27
77·32	85·45
78·00	86·05
78·38 (chief line)	87·50 (double?)
79·45 (double?)	88·10**
80·00	89·85, 90·45 ‡‡
80·20 (double?)	
80·85 "	92·55 (covered)
81·40	93·10**
81·97	95·55
	96·10

* Chief line and evidently a close double. Higgs gives also 78·19 and 78·38, apparently the outer edges.

† End of Higgs' measurements. ‡ This line hidden by adjacent heavy line.

§ Lines bracketed do not appear to fit the series. Perhaps foreign.

‖ Covered by heavy line. ¶ Hidden by heavy adjacent line.

** Stronger on old chart.

‡‡ Hidden by a group of five heavier lines, none of which actually cover the positions but the shading renders them invisible.

Relations between Lines and Bands.

The terms "head" and "tail" or "train" used to designate the two parts of the A, B, and *a* groups cannot be taken in this case in the usual sense of these terms as applied to band spectra, and are really misnomers. The spectrum is composed of two series of entirely separate bands instead of a single series, the so-called "heads" forming the first and the "tails" the second. The first series has the appearance of being nearly all "head" and the second all "tail," but the apparent crowding and confusion in the case of the former is due to the distance between the first few pairs being less than their width. That the "head" and "tail" are really separate bands is apparent from the following considerations.

Both "head" and "tail" begin with pairs of the same width, which decrease in width with increasing wave length in the same manner.

No series in a "head" or "tail" is a continuation of a series in the other as it should be if they were parts of the same band. Also, the first and second differences between homologous lines in the "heads" and "tails" form entirely different series as do the ratios of the homologous lines. Further, while there are no lines in places calculated for the tail series extended upward, faint lines appear to be in the proper places for an extension of the head, just as if the first band, instead of fading out gradually as the second does, should drop very suddenly in intensity on approaching the region occupied by the second. That this is apparently what happens is indicated also by the fact that the last line of what is usually considered the last pair in the "head" of B is scarcely half the intensity of its mate and in *a* is less than half. Extending the series of the first bands of B and *a* we find the following agreement between observed and calculated values.

B		α	
Observed.	Calculated.	Observed.	Calculated.
6879·28 *	----	6284·00 *	----
80·17 *	----	84·75 *	----
81·80	81·85	86·09	86·11
82·72†	82·72	86·88	86·84
84·65	84·67	88·48	88·49
85·54	85·52	89·20	89·20
87·75	87·74	91·14 (covered)	91·14
88·60	88·57	----	91·83
91·05	91·06	----	----
91·87	91·87	----	----
94·67	94·63	----	----
95·50	95·42	----	----

* Last pair of strong lines.

† Hidden by heavy adjacent line.

Indications that the first A band is continued beyond the last strong pair are not lacking though they are not so strong. The other groups are too faint for corresponding lines to be observed in them.

The geometrical relations of both lines and bands are clearly seen in Plates III and IV.

In most spectra it is the vibration numbers which are subject to regular laws rather than the wave lengths, but in this case it makes little difference so far as Deslandres' first law is concerned, which is taken. The first law is but a rough approximation, as is shown by the following application to the second series of the second band of B. The constant b is calculated from the sixth line.

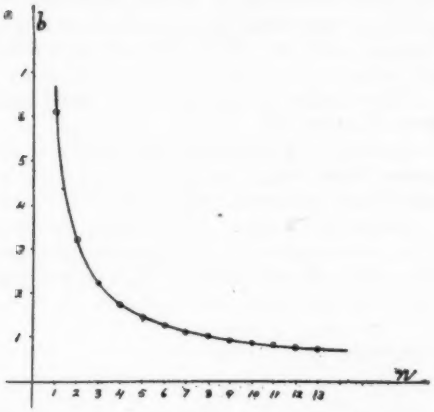
$\frac{1}{\lambda}$ observed.	$\frac{1}{\lambda}$ calculated.	Diff.
14526·27	14526·27	0·00
520·15	524·84	+ 4·69
513·49	520·53	+ 7·04
506·29	513·36	+ 7·07
14498·65	14503·33	+ 4·68
490·42	490·42	0·00
481·70	474·65	− 7·05
472·45	456·00	−16·45
462·72	424·49	−38·23
418·53	319·67	−98·76
406·26	292·92	−123·34

The accuracy of the measurements would allow a variation of only a few hundredths in the last column. The fact is, Deslandres' constant b is not really a constant, at least for this spectrum, as the following values of b, calculated for the different lines of the above series, show:

$b = -6·12$	when $n = 1$	$b = -1·098$	when $n = 7$
$-3·195$	"	$-0·993$	"
$-2·22$	"	$-0·911$	"
$-1·726$	"	$-0·846$	"
$-1·434$	"	$-0·792$	"
$-1·238$	when $n = 6$	$-0·748$	"
		$-0·710$	when $n = 13$

The variations of b are the same for all the bands, except that for the second band series the initial values are always larger than for the first. Also, the values of b for homologous lines of the same band series are nearly constant.

If the values of b for any series are plotted as ordinates and the values of n as abscissæ, curves are obtained which at once suggest a much better law.



The *bn*-curve for sec. series, sec. band, Group B.

The curve, in form, is very nearly an equilateral hyperbola. Assuming it to be such we have

$$bn = k = \text{const.}$$

This, however, is not quite true, but if a correction is made as follows,

$$bn - \frac{n}{c} = k$$

then k is almost exactly constant. Substituting this value of b in Deslandres' formula we have

$$N = a + kn + cn^2.$$

That is, the correction for Deslandres' law is of the first order in n instead of being as usual of a higher order: the constant k is very large compared with c. Both c and k are different for the different series but their variations are small.

The increased accuracy of the new formula is shown by its application to the same series of B calculated above by Deslandres' law. The differences only are given here corresponding to the third column above.

0·00	+0·01	$k = 5{\cdot}86$
+0·00	−0·04	$c = \cdot 2611$
+0·02	−0·07	
+0·05	+0·01	
+0·00	−0·02	
+0·02	−0·05	
+0·01	−0·16	

The second differences of the new formula are constant as they are in that of Deslandres, and it is evident from the near approach to constancy observed in the second differences of both N and λ, that some law based on this property is the true one. That the lines follow some very definite arrangement is seen from the smoothness of the bn-curves and from the smallness of the differences between the observed and calculated values. It is quite probable that the proposed formula will be found to represent the line series of other band spectra more closely than the old. This I have not as yet investigated. Assuming the proposed law to be exact we have on the other hand a criterion of the accuracy of the measurements of the wave lengths. It is quite likely that if the series were longer the formula would need an additional term, possibly one depending on the wave length. This is a matter for further investigation. The formula may have some theoretical importance also, as the formulæ so far deduced theoretically have not contained the first power of n.

Deslandres' second and third laws are only approximate for this spectrum but a correction for them could not be obtained with certainty, owing, in the case of the third law, to the shortness of the band series.

The points of chief importance in the foregoing discussion may be summarized as follows:

1. The general accuracy of the determination of the wave lengths in the groups A, B, and *a* has been greatly increased and the series which compose them considerably extended.
2. The band a' has been measured and its relation to the other groups studied for the first time, and in addition a new band a'' has been observed and studied at $\lambda = 5377{\cdot}2$.
3. The oxygen absorption spectrum has been shown to consist of two distinct series of bands instead of one, the series of bands occuring in pairs just as do the series of lines in a band.
4. Deslandres' first law has been shown to be entirely inadequate to represent the line series of the several bands and a modification is proposed which gives results agreeing with the observed values to about the limit of error of the measurements.

In conclusion I wish to express my thanks to Prof. A. W. Wright, whose kindly interest and criticism have been of great benefit throughout this investigation, and through whose aid the excellent photographs of the spectrum were obtained.

Sloane Physical Laboratory, Yale University.
May 1, 1904.

EXPLANATION OF PLATES II TO IV.

Plate II.

1.—A group ; Kirchhoff. Prismatic spectrum.
2.—A " ; Thollon. " "
3.—A " ; Langley. Grating spectrum.
4.—A " ; Piazzi Smyth. " "
5.—A " ; Cornu. " "
6.—A " ; Drawn from photographs with large Rowland grating in Sloane Laboratory. The last three pairs added from measurements of wave lengths. Comparison was made with Higgs' photographs of A which are probably the best yet taken. The drawing shows all details except the "secondary series." The eighteenth pair is cut off.

Plate III.

The groups as represented in Plate III are drawn from the measurements of the wave-lengths. Beginning with A, they are arranged in order, one above the other, with the first lines of the second bands forming a straight line. This pyramid-like grouping of the bands is especially effective in showing the symmetrical arrangement of the pairs from group to group and their decreasing width from A to a''.

Plate IV.

The distance between the lines marked A and B is 4^{cm}, representing the distance in wave lengths between these two bands. The other horizontal lines are drawn at distances proportional to their distances in wave lengths from A. Plotted in this way the corresponding lines of the several bands fall almost exactly in a straight line, this being especially true for those lines whose wave lengths are most accurately measured.

SCIENTIFIC INTELLIGENCE.

I. Geology and Natural History.

1. *United States Geological Survey.*—The following publications have recently been received:

Professional Paper No. 11.—The clays of the United States east of the Mississippi River; by Heinrich Ries. 287 pp., 9 pls., 11 figs. The origin of clay, its composition, varieties and uses is discussed and its geologic distribution described. The greater part of the paper is taken up with a detailed description and discussion of the clay deposits and the clay industry of the states east of the Mississippi.

No. 12.—Geology of the Globe Copper District, Arizona; by F. L. Ransome. 165 pp., 27 pls., 10 figs.

The oldest rocks of the Globe district are crystalline schists of pre-Cambrian age, which, together with intruded masses of granitic rocks, form the core of the Pinal range. Upon these schists lie a series of shales, conglomerates and quartzites, varying in thickness from 500 to 800 feet, which have been assigned to the Cambrian. Overlying these is a series of limestones with a maximum thickness of about 400 feet. They range in age from Devonian to Upper Carboniferous. In addition to the sedimentary rocks there are large masses of diabase, which were intruded chiefly in the form of silts between the sedimentary beds. Later still, another volcanic eruption brought extension masses of dacite into the region.

The structure and topography of the region is largely dependent upon the great number of faults found in the district. Mr. Ransome says, "Probably few equal areas of the earth's surface have been so thoroughly dislocated by an irregular network of normal faults, and at the same time exhibit so clearly the details of the fractioning."

Mining in the district was commenced in 1874. The early work was done on silver and gold deposits, the copper ores which are the predominant ones to-day not having been seriously worked until after 1881. Since then the quadrangle has produced approximately 120,000,000 pounds of copper.

The copper ores belong to two mineralogical classes: (1) oxidized ores being mostly cuprite, malachite or chrysocolla, and (2) sulphide ores being mostly pyrite and chalcopyrite. The first group has furnished the major part of the ore up to the present. The ore bodies exhibit various forms and may be classed as (1) lodes, (2) masses in limestone and (3) irregular mineralization of shattered or permeable rocks. The lodes are usually simple veins occupying fault fissures. The important ore bodies are those in the limestone. These are usually rudely lenticular in shape, and lie roughly parallel to the bedding of the rock occurring scattered irregularly through it. They are usually either in a prom-

inent fault fissure or closely connected with one. Ores of the third class have also contributed largely to the total output.

The ores were undoubtedly originally sulphides deposited by ascending solutions. The igneous rocks of the district probably have had an intimate influence on their formation by supplying material together with heat and chemical activity to the underground waters.

The report closes with a detailed description of some of the more important mines, including maps and sections of the workings. W. E. F.

No. 16.—The Carboniferous Formations and Faunas of Colorado; by GEORGE H. GIRTY. 546 pp., 10 pls. The first 216 pages of this work are devoted to a useful review of the literature and discussion of the interpretations of the geology and paleontology of the Colorado region given by previous writers. In the second part, pp. 217–267, the author discusses the faunal evidence and correlations furnished by the material under investigation; and in the remainder of the volumes (pp. 268–546) the species are described and figured.

The result of study of the collection shows the presence of both Mississippian and Pennsylvanian faunas.

The Mississippian fauna occurs in the Leadville limestone and its equivalents, the Ouray and the Millsap limestones. These are interpreted as equivalent to the Kinderhook and lower Burlington faunas of the Mississippi valley region.

To the Pennsylvanian are referred the Hermosa, Weber, Maroon, Robinson, Molas, and Rico formations. Essentially the same fauna is reported from the Hermosa, Weber, Lower Maroon of the Crested Butte section, and from the Weber shales and grits of the Leadville section. This fauna is considered by the author to be older than any of the Pennsylvanian beds of the Kansas and Nebraska sections. The Rico formation is by its fauna interpreted as probably of about the horizon of the Deer Creek, Hartford and Howard formations of Kansas. H. S. W.

No. 17. Geology and Water Resources of Nebraska West of the One Hundred and Third Meridian; by N. H. DARTON. 66 pp., 43 pls., 23 figs. With a few minor changes this paper is a reprint of pp. 719–785 in the Nineteenth Annual Report.

No. 19.—Contributions to the Geology of Washington. 98 pp., 20 pls., 3 figs. This publication contains two papers: Geology and Physiography of Central Washington; by GEORGE OTIS SMITH, and Physiography and Deformation of the Wenatchee-Chelan District, Cascade Range; by BAILEY WILLIS. During Pliocene time a lowland surface was developed in Central Washington and the ancient controlling drainage system may possibly be indicated. This plain was uplifted and warped so that the Cascade range is complex in type. Geologic processes worked rapidly in this region, as is shown by the Eocene section of 10,000 feet divisible into four distinct formations, separable both by physical breaks and differences in fossil flora. The unique char-

acter of this region is the modification of the peneplain by warping so as to form anticlinal ridges and synclinal valleys. In the Wenatchee-Chelan district glaciation furnishes an additional datum plane and Mr. Willis has worked out the physiography in great detail. He recognizes five physiographic stages from the Pliocene to the Recent, inclusive. As a study of physiographic method and of criteria for recognizing peneplains this paper is a valuable addition to geologic literature.

2. *Alaska, Glaciers and Glaciation;* by G. K. GILBERT, being Vol. III of the Harriman Alaska Expedition reports, published with coöperation of the Washington Academy of Sciences. New York, 1904. (Doubleday, Page & Co.) 231 pp., 18 maps and plates, 106 figs.—This most instructive and suggestive report may be briefly reviewed under four headings: preglacial land forms, erosion by Pleistocene glaciers, existing glaciers, and glacial erosion in general. A noteworthy feature of the preglacial topography was the occurrence of mountain ranges formed by the broad uplift and dissection of extensive peneplains, which, it may be here noted, are but so many additional instances of the difficulty into which Suess's hypothesis of the origin of horsts must lead the geologist. These peneplains and the neighboring ocean were once at (almost) the same level: according to Suess' hypothesis, the peneplains have become horsts, not by local elevation, but by the depression of the surrounding surfaces; and in this case, as in many others where horsts have ancient peneplains for their uplands, it is evident that such an explanation involves the depression of all the oceans of the world, and the continents along with them, the horsts alone standing still. This is of course conceivable, but it is an extravagant conception. Certain parts of the coast show lowlands of denudation adjacent to the mountains, thus recalling the coast plain of Norway as described by Reusch. Gilbert explains the Alaskan coast plain by general erosion when the land had gained something like its present altitude, and does not explicitly call upon marine erosion, as Reusch did for the Norwegian example. Erosion of valleys to a greater depth during a time of greater elevation is also inferred, but hardly proved, unless it is held that glacial erosion cannot have scoured out the channels now occupied by the sea while the land held its present position.

Gannett's thesis that a glaciated valley is comparable with a river channel is supported by a great variety of facts. Cirques and hanging valleys characterize the coastal mountains: repeated examples are figured and described. In this connection reference may be well made to the Chief Mountain (Montana) map sheet, lately issued by the U. S. Geological Survey, an elegant example of fine topographic work by Messrs. Matthes and Sargent, in which cirques and hanging valleys are remarkably well portrayed. Indeed so numerous are the examples of these forms in once-glaciated mountains in many parts of the world that the occasional occurrence of imitative forms in non-glaciated districts can

hardly be used, as they lately have been by Russell (Science, May 20, 1904, 785), to throw doubt on the glacial origin of normal cirques and hanging valleys. It may be difficult to explain the imitative forms, but as the matter now stands, it is their explanation that is deficient, and not the explanation of the normal forms by glacial erosion as stated by Gannett and Gilbert. True, the trunk valleys are often so much deeper than the hanging lateral valleys as to make it very difficult indeed to ascribe their excess of depth to glacial erosion ; yet the hesitation that one may feel here is more likely to be based on a conservative habit of thought than on direct argument ; for the valleys are certainly valleys of erosion, and when it is once shown that glaciers are effective erosive agents, it does not appear more unreasonable to ascribe the great trough valleys to the work of frozen water than to that of molten water. It is pointed out by Gilbert that the main valley sides are relatively smooth and trough-like, sometimes exhibiting details of form that suggest the action of an eroding agent which moved in nearly horizontal lines, and thus contrasting strongly with the ravined valley sides of non-glaciated mountains, where the agent of erosion has manifestly worked on down-slope lines. The extension of these main valleys across the coast plain leads to the conclusion that their erosion was accomplished by the larger glacial streams in consequence of their relatively great velocity ; thus agreeing with the opinion reached by Richter for the over-deepened valleys of the Alps.

The existing glaciers are described and illustrated in much detail, with especial reference to their recent variations. It is shown by a careful comparison of all available descriptions, maps and photographs, that the changes of the glaciers have been singularly discordant during the past century, and the discordance is held to be too great to be explained by lagging. A most ingenious suggestion is then made that under certain changes of mean temperature, one set of glaciers might be caused to advance while others near by would be compelled to retreat. Glacial students who visit Alaska during the present century thus have a pleasing problem set before them for solution.

The volume closes with some general conclusions as to glaciers, in which we find an altogether new view as to the possibilities of glacial erosion beneath the sea. It has been recognized in recent years that the invasion of once-glaciated valleys by the sea was not, as it has usually been regarded, an evidence of submergence, for heavy glaciers can certainly erode beneath sea level. Gilbert now gives reasons for thinking that heavy tidal glaciers are not effectively buoyed up by the water that they enter, and that they erode beneath sea level about as effectively as on a land surface. If this should be fully demonstrated, it would lead to a radical change of opinion regarding the changes of level indicated by fiord coasts. "Plucking" is looked upon as of great importance in glacial erosion. W. M. D.

3. *The Origin and Relationship of the large Mammals of North America and the Caribou;* by MADISON GRANT, Secretary of the New York Zoological Society.—These articles, reprints from the annual (eighth and seventh) reports of the New York Zoological Society, form an exceedingly interesting volume of about 60 pages, copiously illustrated by 32 exceptionally fine plates, reproductions of photographs of the caribou in their native haunts, in captivity in the N. Y. Z. park, and of mounted specimens in the American Museum. A map showing the distribution of the two kinds in North America is also given. The purpose of the first article, as stated by the author, is "to briefly review the living large mammals of the United States and Canada, and to endeavor to trace their past history," such an analysis being possible because of the increase in knowledge of the true relationship of mammals and their geographical distribution greatly aided by the definite proofs given in recent paleontology. The facts are very clearly presented in concise divisions showing the existence of two definite continental radiations, proved by distinct faunal groupings showing geographical origin and connection, followed by a discussion of the various distinct groups of animals themselves with a table showing their derivation, concluded by a summary of previously mentioned facts. In the second article, the facts correlated in regard to the caribou are presented in a similarly clear manner, showing the origin of the name, classification of the various species with their geographical origin and distribution. K. J. B.

4. *The Mammals of Pennsylvania and New Jersey;* by SAMUEL N. RHODES.—This volume (privately published) of 266 pages with 9 plates (reproductions of photographs) and faunal map is, as shown by the title page, a "biographic, historic, and descriptive account of the furred animals of land and sea, both living and extinct, known to have existed in the states of Pennsylvania and New Jersey" and is "designed as both a popular and scientific presentation of a branch of nature-study hitherto unduly neglected." Among the many valuable facts given in the introduction, one of especial interest is that "the list of fossil mammalia found in these two states far exceeds that of the rest of the United States east of the Mississippi river." This is due to the researches of Leidy, Cope, and Marsh among the fossil-bearing limestone caves and fissures in the Delaware valley and in the marl beds of New Jersey. Above 90 species are cited of which 30 are found still existing; these, with over 70 living species and 25 sub-species or geographic races, show not only a surprisingly large mammalian fauna, but also the noteworthy fact that the fossil fauna exceeds that of the living. The vast amount of careful labor expended in compiling this valuable work will be appreciated by all students, and writers on kindred subjects. K. J. B.

5. *Medusæ of the Bahamas;* by ALFRED GOLDSBOROUGH MAYER. Memoirs of Natural Science, vol. I, No. 1, of the Museum of the Brooklyn Institute of Arts and Sciences.—This article of 33 pages, with 7 heliotype plates, is based on observations

made by the author during June and July, 1903. Of the 43 species found, 5 are known only from the Bahamas, 2 of which are locally abundant. Among them, one genus (*Paranemus*) and two species are new to science. The opportunity of studying asexual budding was afforded by a most interesting example of *Eucheilota paradoxica*. The paucity of the medusa-fauna of this locality compared with that of Tortugas, Florida, is given as being largely due to local conditions. The former being situated to the windward, while the latter is to the leeward of the Gulf Stream, is depleted by the prevailing winds, and is poor in those creatures which are mainly dependent upon great currents for their distribution. K. J. B.

II. Miscellaneous Scientific Intelligence.

1. *International Congress of Arts and Science at the Universal Exposition, St. Louis.*—An International Scientific Congress will be held at St. Louis from Sept. 19–25, in connection with the Universal Exposition. Professor Simon Newcomb is the President of the Congress and Professors Hugo Muensterberg and A. W. Small the Vice Presidents. The whole field of knowledge is divided for the purposes of the Congress into seven divisions, these further into twenty-four departments and these finally into some 128 sections. The official program contains the following statements:

"After the opening of the Congress on Monday afternoon, September 19, will follow, on Tuesday forenoon, addresses on main divisions of science and its applications, the general theme being the unification of each of the fields treated. These will be followed by two addresses on each of the twenty-four great departments of knowledge. The theme of one address in each case will be the Fundamental Conceptions and Methods, while the other will set forth the progress during the last century. The preceding addresses will be delivered by Americans, making the work of the first two days the contribution of American scholars. On the third day, with the opening of the sections, the international work will begin. About 128 sectional meetings will be held on the four remaining days of the Congress, at each of which two papers will be read, the theme of one being suggested by the Relations of the special branch treated to other branches; the other by its Present Problems."

The list of distinguished scholars, from Europe and America, announced as speakers at the Congress, ensures it an eminent degree of success in its grand object of "the unification of knowledge."

2. *Geographen Kalender, 1904–1905*, edited by Hermann Haack; 290 pp., 16 maps: Gotha (Justus Perthes).—There is no one publication which serves so well the purpose of an annual reference book of geographical matter as Dr. Haack's "Kalender." New explorations, adjustments of boundaries, development of canals, railroads, etc., are described and mapped. To this are added a list of addresses of scientists and societies, a review of the year's geographical literature and a mass of useful statistics.

Obituary.

John Bell Hatcher, Curator of Vertebrate Paleontology in the Carnegie Museum at Pittsburgh, died of typhoid fever at Pittsburgh on July 3, 1904. By his death Paleontology has lost an investigator and writer of unusual ability, a man who had few equals in his chosen line of research.

Born at Cooper, Green County, Iowa, October 11, 1861, his early years were passed among surroundings and under conditions which developed a character of absolute integrity and of rare self-reliance and determination. He entered the Sheffield Scientific School of Yale University in his twentieth year, when he improved to the utmost the educational facilities offered to him. Although a few weeks before the graduation of his class, in 1884, he expressed himself as being still uncertain in his choice of future occupation, it is on record that during his college course he gave especial attention to those studies in Natural History which fitted him for his life's work. Probably Hatcher's marked ability had already become known to the late Professor O. C. Marsh of the Yale University Museum, who secured his services as field collector. Hardly waiting until the close of his graduation exercises, he left New Haven on June 25, 1884, for the West, where he collected in Kansas and Nebraska for about a month, under the direction of Charles H. Sternberg. Later he commenced work by himself, and remained in the field alone until the approach of winter, when he returned to New Haven. When not in the field, much of Hatcher's time was spent in preparing and studying the fossils he had collected, and in making himself generally familiar with them as an aid to further collecting. He also pursued advanced studies in Botany with the late Professor D. C. Eaton, who became sincerely attached to the young scientific worker, and who always expressed the highest regard for his character and ability. In 1885, after collecting Permian fossils in Texas, Hatcher returned to Kansas and continued his work in the Pliocene formations. The seasons of 1886 and 1887, which were spent in the Bad Lands of Dakota and Nebraska, won him renown as a collector. From the famous "Brontotherium Beds," he shipped to the East carload after carload of fossils, including the bones upon which Marsh founded his genera *Brontotherium* and *Protoceras*. In fact, Hatcher's labors in the field were of inestimable value, and the collections made by him, more than those of any other of his scientific assistants, furnished to Professor Marsh the material for his paleontological work.

By this time, Hatcher's services had become so valuable that Marsh kept him constantly in the field. The winter months were spent in Maryland, Virginia and North Carolina. The variegated red and gray clays conspicuous between Baltimore and Washington had long been a puzzle to geologists. Many collectors had visited the outcroppings, but had failed to obtain characteristic fossils at the typical localities. Hatcher, whose

keen eyes were fresh from the western fossil beds, was entrusted with the work. In two months he brought together a collection in which were abundant dinosaurian remains associated with the bones of other reptilian orders.

The summers of 1889 to 1892 were spent in Converse County, Wyoming, where Hatcher obtained a magnificent collection of Ceratopsia material. One of the best known types of this group is Marsh's *Triceratops*, now exhibited in the Yale University Museum. Another notable dinosaur collected by Hatcher is the *Claosaurus*, mounted at Yale by Professor Beecher after Marsh's death. When the latter retired from his position of Vertebrate Paleontologist of the United States Geological Survey, in 1892, funds were no longer available for collecting on so extensive a scale, and Hatcher severed his connection with the Yale Museum. Shortly after, he became Curator of Vertebrate Paleontology and Assistant in Geology at Princeton University. His work during the following years won him the highest praise. In spite of great hardships, he successfully made collecting and exploring expeditions into the wilds of Patagonia. Neither ill health nor accidents, such as the loss of his saddle and pack animals hundreds of miles from any source of supplies, could daunt him, and his work in the southern continent proved not only of the highest value to the naturalist and paleontologist, but his chronicle of these expeditions is also of great interest to the general reader.

In 1900 he accepted the Curatorship of Vertebrate Paleontology in the Carnegie Museum at Pittsburgh, which position he filled with honor to himself and to the great improvement of his department. Engaged by the United States Geological Survey to continue Professor Marsh's work on the Ceratopsia, he had nearly finished that difficult task, involving a careful study of the material at Yale and at the National Museum, which he had himself collected years before. His talent and industry had already won him an enviable position among paleontologists, and he had just accepted the Curatorship of Vertebrate Paleontology in the United States National Museum, when his untimely death occurred.

Hatcher's reputation as a paleontologist rests mainly on his work upon the fossil Reptilia, his principal contributions appearing in the Memoirs of the Carnegie Museum, under the titles of "Diplodocus Marsh," and "Osteology of Haplocanthosaurus." His valuable treatise entitled "Oligocene Canidæ" was published in the same form. Latterly Hatcher developed considerable talent as a stratigrapher, as is shown by his memoir on *Haplocanthosaurus*, the records of the Patagonia Expeditions, and by other shorter publications, which is the more remarkable inasmuch as many able paleontologists have shown little skill in this branch of geology.

Of marked avidity for the hardest work, and of quick and accurate discrimination in his scientific labors, Hatcher accomplished much during his short career. His constant loyalty and thoughtful kindness endeared him to those who were so fortunate as to enjoy his intimate friendship. GEORGE F. EATON.

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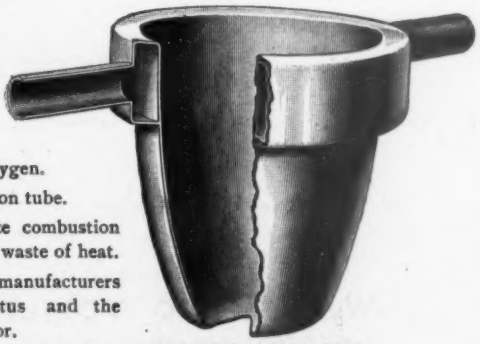

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